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Photo Illustrating Service

Basque peasants in the cherry-growing region of the Pyrenees
THE CHERRY CROP OF FRANCE—[See page 280]

Modern Methods of Progress*

The Relation of Research to Industrial Development

By Arthur D. Little†

I ASSUME with confidence that few if any of you have come here in the attitude of mind of that American steel maker in a small and remote town who, years ago, when his directors decided that their interests might be furthered if he were to employ a chemist, wrote back:

"Send down one who can play the violin. We can stand his damned nonsense in the daytime if he will amuse us in the evening."

The railway, as it serves you, is not the casual invention of Stevenson. It is the product of many decades of industrial research by Bessemer, Westinghouse, Pullman; by Dr. Dudley, who standardized its materials and supplies, and by countless chemists, engineers, mathematicians and physicists whose contributions to the common stock of knowledge made possible the development of its equipment, in at least as real a sense as it is the creation of the great organizers, audacious capitalists, and wise executives with whom its development is commonly associated in the public mind.

The telegraph as it came from the hands of Morse was a feeble and restricted means of communication. It carries the burden placed upon it by the business world today only because it embodies the results of protracted research by Wheatstone, Siemens, Stearns, Edison, Murray and Rowland, which have many times multiplied the working capacity and operating length of telegraph lines.

The telephone, although initially a product of the most refined research, was, when first given to the world by Bell, little more than a scientific curiosity, as halting and uncertain in its speech as a child of three. Today for the purpose of a conference it brings the people of a continent into one room and even carries the human voice from New York to Honolulu because it has passed through the laboratories of Berliner, Edison, Hughes, Blake, Hennings, and Carty, where in each instance new possibilities and powers have been bestowed upon it by intensive and prolonged research. Wonderful and seemingly perfect as the instrument is today, the American Telephone and Telegraph Co. finds it profitable to authorize its chief engineer, Mr. J. J. Carty, to expend for industrial research a greater sum than any other man in the world has at his disposal for such purpose.

The silent dynamo, instinct with power, supplies the current which lights our streets and homes and factories, drives our machinery, fires electric furnaces, creates new products in electrolytic cells, and is our ready and ever willing servant responding in countless ways to our demands. It so serves us only because Faraday by refined research stimulated and directed by the scientific imagination at its best, developed the underlying principles on which its operation depends.

The ocean steamship from wireless to propeller is a microcosm of the results of research without which it would be a scow. The harvester is the embodiment of years of systematic experiment.

I challenge you to name a business from shoe blacking to banking which is not vitally interested in the application of research results. In the earlier days of shoe blacking Bixby's paste and Day & Martin's liquid sufficed for all demands of the most exacting customers of the peripatetic polisher of shoes. The modern boot black applies a first coat, the formula for which has been worked out in the laboratory, and finishes off with a wax emulsion prepared in accordance with the latest teachings of the chemistry of colloids. He has a gum tragacanth paste for cleaning tan shoes and a tan paste appropriately colored by synthetic dyes for the polishing, something else for patent leathers, and Blanco for white shoes. Here are the statistics which prove it as regards some manufacturers in the United States.

There are in the United States over 250,000 corporations. Over 100,000 of them report no net income whatsoever. Ninety thousand make less than \$5,000 a year. Only 60,000 make \$5,000 a year or more. Making all allowances for lack of capital, bad credits, and all the other commonly recognized causes of industrial disaster, I do not hesitate to say without fear of successful contradiction that the chief cause for this amazing and discreditable showing is due to the failure of small manufacturers to utilize that vast body of organized knowledge which the research of the last one hundred years has placed within their reach.

This is merely reiterating what was said years ago by

that distinguished Canadian who has done more than anybody else to spread the gospel of industrial research in the United States, Dr. Robert Kennedy Duncan, the founder of the Mellon Institute at Pittsburgh. In his "Chemistry of Commerce," a book which I can highly recommend to all of you, Dr. Duncan says: "The small manufacturer who is swept out of existence will often wonder why. He will ascribe it to the economy of large scale operations, or business intrigues or what not, never knowing that his disaster was due to the application of pure science that the trust organizations and large manufacturers already are beginning to appreciate."

To this may well be added these words of J. J. Carty, the world's greatest telephone engineer:

"In the present state of the world's development there is nothing which can do more to advance American industry than the adoption by our manufacturers generally of industrial research conducted on scientific principles. . . . Those who are the first to avail themselves of the benefits of industrial research will obtain such a lead over their competitors that we may look forward to the time when the advantages of industrial research will be recognized by all."

Among those who have made the advancement of the boundaries of human knowledge their life's work there still remain a few who regard science as a sort of private preserve for intellectual sportsmen and who draw an esoteric distinction between pure and applied science. With them research acquires sanctity in proportion as its results seem unlikely to be of any earthly use, while research, which has for its avowed object the satisfaction of some human need, is assumed to be tainted with commercialism and to involve a lower order of intellectual merit and achievement.

But the alarm clock has been heard even in laboratories devoted to so-called pure science and the splendid work of such great research laboratories as those of the General Electric Company and Eastman Kodak Company have amply demonstrated that the solution of industrial problems affords full scope for the highest scientific intellect and training. To again quote J. J. Carty, "In the last analysis the distinction between pure scientific research and industrial scientific research is one of motive."

Fortunately also for the world the most self-centered investigator can make no addition to the sum of human knowledge which may not some day become a milestone of industrial progress.

The scientific study of the atmosphere to which Englishmen have so conspicuously contributed was for the most part carried on with no thought of making an industrial application of the results obtained. In 1785, Cavendish recorded the production of nitric acid on the passage of an electric spark through the air. Five hundred thousand horse-power are now employed in turning that discovery to practical account in the fixation of atmospheric nitrogen, in Norway alone. Recently, as it still seems, Dewar succeeded in liquefying air and in separating the oxygen and nitrogen by fractional distillation. Already this separation constitutes a fundamental factor in the methods for the production of synthetic ammonia, and the manufacture of the nitrogenous fertilizer known as cyanamid. Incidentally Dewar invented the thermos bottle as a container for liquid air.

Still more recently Ramsey demonstrated the existence in the atmosphere of five rare and unknown gases with unique properties. Of these argon is now manufactured in quantity in Canada and obtainable in liquid form in cylinders. To another, neon, we now confidently attribute the long mysterious phenomena of the aurora borealis. Tubes containing highly rarified neon may become as common to our descendants as candles to our ancestors. They glow with a rich, mellow golden light on the passage through them of an electrical discharge.

There are few men to whom the world stands in greater debt than to the French chemist, Pasteur. There is probably not a man in this room who is not under heavy obligation to him and except for his discoveries some of you would not be here at all. His demonstration of the germ theory of disease and the development of the serum and antitoxin treatments have saved more lives than the present awful war has cost all the belligerents combined. Such service is beyond estimate in monetary terms, but the direct financial value of Pasteur's discoveries was years ago appraised by Huxley as sufficient to cover the whole cost of the war indemnity paid by France to Germany in 1870.

In 1865 a fatal epidemic among the silk worms had ruined the silk growers of France. In June of that year Pasteur was called to the south of France to study the disease. In September he announced the method which proved successful for its control. Other studies saved the French wine industry from the destructive ravages of phylloxera, stamped out chicken cholera and anthrax, and for the first time put brewing and wine making on a scientific basis. Of him the English chemist, Sir Henry Roscoe, has said: "What was the secret power which enabled Pasteur to bring under the domain of scientific laws phenomena of disease which had so far baffled human endeavor? It simply consisted in the application to the elucidation of these problems of the exact methods of chemical and physical research."

To each one of you I commend the statement of Pasteur himself that "in the field of observation chance only favors those who are prepared."

Chance favored a man who was prepared when in 1828 the German chemist, Wohler, set aside to crystallize a solution of the inorganic compound cyanamid, only to find that the crystals which were deposited were those of the organic compound urea. The moment that observation was made the wall which in the minds of men had divided the organic from the inorganic world crumbled and disappeared and the science and industry of organic chemistry followed in logical and orderly development. In one department of the new science that boy of eighteen who later became Sir William Henry Perkin derived a dye stuff, mauve, from coal tar aniline and laid the foundation for an industry in which a capital of \$750,000,000 is now employed.

Some of our greatest industries are concerned with the art of illumination and adequate illumination is in itself an important factor in determining the productive capacity of industrial plants. How would your blank sheet stand if your factory was lighted with tallow dips?

The pulling of a chain, the pushing of a button now floods a room with brilliant light, solely because science during the past one hundred years has been applied to the problems of illumination. The gas works in every municipality, the great oil companies whose names are synonymous with organized and profitable industry, the electric light plants, the carbide factories, the establishments throughout the world devoted to the manufacture of incandescent lamps, gas mantles, and countless other details of equipment are founded not on capital not even on organization, but in the last analysis upon science. They owe their existence to the applied research of Murdock which developed gas from coal, of Lowe which led up to the gas producer, of Welsbach which discovered in the monazite sands of faraway Brazil the elements which so greatly raised the illuminating power of gas as to save the industry from what seemed to be the overwhelming competition of the incandescent lamp, of Wohler and Willson which gave us carbide and acetylene with oxyacetylene welding and the nitrogenous fertilizer cyanamid as by-products, of Davy which demonstrated the arc lamp, of Edison, Swan, Malignani, Howell and Coolidge, which initiated and developed that scientific marvel the incandescent lamp and other unnumbered and perhaps forgotten workers who in their laboratories fabricated each his part of the structure of the industry.

An evening might be spent on a bare outline of what research has already accomplished for the steel industry. It promises to do still more. The microscopical structure of steel is a subject of daily study in more than two hundred laboratories in the United States alone. Many other evenings might be devoted to the exposition of the benefits of research in many other industries. And if the survey were complete no industry would be omitted.

Since, however, both your time and patience have their limits such a survey, however informing and convincing it might be, is impossible. But I venture to ask you to consider briefly with me some of the industrial developments which have resulted from research in a single field of chemistry with which I happen to be especially familiar. I refer to the chemistry of cellulose.

Cellulose is the greatest structural material in the world. At least ten billion tons of it are produced by Nature every year. Without it the earth would be bare of vegetation, an arid waste without grass or trees or flowers. There would be no agriculture, no lumbering, or textile, cordage, or paper industry, no food for animals and consequently no food for man.

Cellulose constitutes the structural basis of all vegeta-

*From an address before the Canadian Manufacturers Association at Toronto.

†President of Arthur D. Little, Limited, directors of Natural Resources Survey of Canada.

tion. It is the material out of which plants build up the infinite variety of form and tissue which, more than anything else, perhaps, makes the world a pleasant place to live in and a storehouse of material adapted to human needs. The cell is the unit of plant structure and cellulose is the predominating constituent of the cell wall. Carefully purified cotton, as in the form of absorbent cotton, is practically pure cellulose in a particular structural form, but cellulose itself is colorless and transparent. It is remarkably strong and tough and singularly inert to the action of reagents. Dry wood is largely cellulose, spruce, for example, containing fifty-one per cent, and the vegetable fibers all consist of cellulose in more or less impure or modified form.

Obviously the textile industries, so far at least as the vegetable fibers like linen, cotton, ramie and so on, are concerned, are directly based upon the properties of cellulose. Any increase in our knowledge of these properties at once reacts upon these industries. When it was found for example, that under regulated conditions cellulose would resist the action of chlorine, while the impurities associated with the cellulose were destroyed, the old grass bleach was soon superseded by the chlorine bleach. When it was discovered that an alkaline boil would dissolve most of these impurities, leaving the cellulose substantially unharmed, the rapid methods of the modern bleaching replaced the long exposure to sun and dew. In 1851 John Mercer noticed that the exposure of cellulose in the form of cotton yarn or cloth to a strong solution of caustic soda greatly strengthened the yarn or fabric and surprisingly increased its capacity for taking dyes. Unfortunately it shrank the fabric. Later to overcome this shrinkage, Thomas and Prevost subjected the yarn to heavy tension while still wet with caustic. The result went far beyond their expectations. Under the tension the twists and irregularities of the cotton fiber disappeared and the yarn assumed an amazing silky luster. What was practically a new fiber was given to the world and it speedily revolutionized the manufacture of the finer sorts of cotton textiles.

Similarly, the paper industry has been revolutionized by three fundamental chemical facts, namely, that the impurities associated with cellulose in wood can be dissolved under heat and pressure by caustic soda, by solutions of sulphites, and by solutions of sulphides. Upon the first is based the soda process for wood pulp, upon the second the sulphite process for wood cellulose, and upon the third the sulphate process for kraft pulp and paper.

In 1819 Braconnot boiled up some cellulose in the form of an old shirt with sulphuric acid and found that the cellulose was converted to a sort of sugar, some of which he subsequently fermented into alcohol. He exhibited his results to the French Academy to the amazement of its members. A hundred years of industrial research has at last transformed that laboratory method into a commercially operative process, by which thousands of gallons of high grade ethyl alcohol are made from yellow pine sawdust. This is not wood alcohol but is identical in every particular with that commonly made from grain. The industrial importance of this achievement can hardly be overestimated. A cord of sawdust costing fifty cents yields ten gallons of ninety-five per cent alcohol whereas a bushel of corn costing over eighty cents yields only two and one-fourth gallons, and a gallon of molasses worth at least fifteen cents gives only half a gallon of alcohol. By this process any vegetable waste which can be collected cheaply and in quantity becomes a raw material for alcohol and releases for their proper use as a food the corn and molasses now diverted to alcohol production. Incidentally it removes substantially all menace of a possible failure of the gasoline supply, since alcohol is equally available as a motor fuel.

In 1846 Schonbein in studying the effect of strong sulphuric acid upon cellulose in the form of paper observed that the paper was thereby converted to a sort of membrane, and in the following year Pomarede and Figuier began the manufacture of the now well-known parchment paper, which, because of its grease-proof property, is largely used for wrapping food products.

A later observation that cellulose is rendered gelatinous by a strong solution of zinc chloride led directly to the manufacture of the vulcanized fiber so largely used as an insulating material and the production of innumerable articles in which lightness, strength and wearing quality are desirable. The vulcanized fiber is so dense and tough that it dulls the edge of cutting tools more quickly than sheet steel.

The observation that cellulose will dissolve in a solution of copper oxide and ammonia is the basis of the well-known Willesden method for rendering cloth and paper, water and insect proof. It led to the production of the first successful filament for incandescent lamps and is the essential feature in an important process for the manufacture of artificial silk.

Girard in studying cellulose noted that when the ma-

terial is moistened with any dilute mineral acid and then dried, it is changed to a friable substance known as hydro-cellulose. On this simple fact depend the processes for removing burrs from wool, cotton from mixed goods, and cotton and other fibers from recovered rubber.

Few discoveries have been more far-reaching in their influence than the observation by Schonbein in 1845 that cellulose on exposure to nitric acid was converted into a new and highly explosive product. For seventy years research has been focused on that observation. It led von Lenk and Abel to gun cotton; Viele, Nobel, Abel and Dewar to various forms of smokeless powder. It revolutionized warfare. It led Hyatt to celluloid, Goodwin to photographic films, du Chardonnay to artificial silk, and is the underlying fact on which is based the manufacture of patent leather, artificial leather, lacquers and a bewildering variety of other products which are everywhere in daily use. Hundreds of millions of feet of nitrocellulose film carry their message of instruction or amusement to hundreds of millions of people in the tens of thousands of moving picture theaters throughout the world each year.

In 1893 Cross, Bevan and Beadle in London conducted a series of experiments which led to the discovery that when cellulose in the form of cotton or purified wood fiber is exposed to the simultaneous action of caustic soda and bisulphide of carbon, a new compound is formed known as cellulose xanthate or viscose, and constituting a golden yellow, plastic mass which is soluble in water. The compound is peculiar in that it may readily be decomposed by heat or acid with recovery of the cellulose in whatever form has been impressed upon the plastic mass, or the solution. Chemists in every land were soon applying this compound to the most diverse industrial uses. It has been used for strengthening and coating paper, printing topical effects upon cotton cloth, for making water paints, as a substitute for glue, for making billiard balls, valve wheels and hundreds of small turned articles, and was in the year before the war the raw material for the production of twenty million pounds of artificial silk worth at a low estimate \$35,000,000.

In our own laboratory the study of the action of acetic anhydride upon cellulose has led to the development of methods for the production of non-inflammable films for photographic and other purposes, waterproof artificial silk, a special insulation for the very fine wires used in electrical recording instruments, automobile goggles, lacquers, varnishes for aeroplanes, and other special products. The cellulose acetate which forms the basis of these products reproduces to a remarkable degree the physical properties of celluloid while possessing the important advantage of being non-inflammable.

When Abram S. Hewitt said that the Bessemer process for making steel adds \$2,000,000,000 yearly to the world's wealth the figure was impressive but not wholly satisfying. It led us to wonder how much of that two billion came to us and where we put it. Perhaps if we deal in smaller figures we can keep track of our profits more easily. Not long ago a manufacturer was heard to say that he would give a million dollars if he could solve a certain technical problem which had arisen in his business. It was suggested that he take his problem to the Mellon Institute. He did so. The problem was there solved in eight hours and I believe he still has the million. We ourselves treasure a letter from a grateful client operating three large shoe factories which bears testimony to the fact that a certain research which we conducted for him has during the past two years saved him weekly more than the entire cost of the investigation. One hundred per cent a week is surely a satisfactory dividend, even where industrial research is concerned. It raises the suspicion, however, that possibly we should revise our system of charges.

A few of you may remember that in pre-prohibition days beer commonly became cloudy when placed on the ice. It was an objectionable tendency which the best skill of the brewers was unable to overcome. A little research by a clever chemist proved that the cloudiness results from the deposition of albumenoids previously in solution. He remembered that pepsin digested albumen, added a trace of pepsin to the beer, and the thing was done. The beer remained bright at any temperature.

Not long ago a Jewish client brought to us a leather stain for which he was paying eighty-five cents a gallon. It proved to be water with a little gum tragacanth and still less aniline dye. We showed him how to make it at a cost of less than ten cents a gallon. He said he began to realize where the Gentiles get the money the Jews get from the Gentiles. In a plant near Boston using two tons a week of special steel, rolled very thin, their chemist was able in about two years to reduce the cost of this material from eighty to forty cents a pound, while at the same time standardizing and greatly improving the quality of the steel. Broken rails are more expensive than analyses and there are no dividends in broken

trolley wires, defective castings, spotted or tendered piece goods or rejections in any line of manufacture. Competition is difficult when your wastes are your competitor's profit.

At no place in the world are the results of industrial research more strikingly evident than at Niagara Falls. The electrical energy derived from a small fraction of that stupendous flow produces, in its passage through electric furnaces and decomposing cells, aluminum, metallic sodium, carborundum, artificial graphite, chlorine, and caustic soda, peroxides, carbide, cyanamid, chlorates and alundum. The story of the electro-chemical development behind these products is an epic of applied science.

Most of the great corporations in the United States have awakened to the commercial value of research. They do not hesitate to spend great sums in the maintenance of superb laboratories and their scientific staff. They expect research to pay dividends and it does not disappoint them. One American corporation employs six hundred and fifty chemists.

Research of this great scale is of course wholly beyond the means of the average manufacturer, but it is also beyond his requirements. These are well served by such an agency as the Mellon Institute at Pittsburgh or by group laboratories maintained by trade associations or by the higher grade of commercial laboratories which are almost institutional in character.

A very large proportion of industrial problems are problems in applied chemistry. Many of these so-called problems have already been solved somewhere. The present need of industry is not so urgent for new research and for new facts as for the immediate and proper utilization of facts already known and demonstrated.

By way of suggestion let me point out a few of the more obvious fields of application for the research method.

There is first the control of quality of raw materials as in case of steel, alloys, bearing metals, lubricants, coal, paints, paper, cement, and practically everything else you buy.

Second, perhaps, is the problem of finding suitable substitutes for such supplies as are unobtainable or unduly high in price. For example there is the use of selenium in place of gold in the production of ruby glass, the substitution of tungsten points for platinum in spark plugs, of silica ware for platinum dishes for the concentration of sulphuric acid, of casein for glue, of chlorate of soda for chlorate of potash in dyeing, of zein, derived from corn, for the prohibited shellac for varnishing confectionery, of specification oils for oils whose value is largely in brand names, and of the specific indicated chemicals in place of high priced boiler compounds.

Of even greater importance is the scientific control of processes of production, control of formulas, temperatures, pressures, time and spacing, fineness of material, moisture content, and all the other factors which influence the quality and amount of your daily output. Correlative with such control are the studies having for their object the standardization of your product and the elimination of seconds and rejections.

Wastes can be minimized and often turned to profit by well-directed research. The waste liquor of the sulphite mills is now a source of alcohol and of adhesives. Barker waste is an excellent raw material for certain low grade papers. The Cottrell process of electrical precipitation effects the recovery of values of smelter fumes, cement dust, and many other chimney products. In some industries, as lumbering, the potential values in the wastes are greater than the realized values in the product.

The wholly abnormal conditions under which business everywhere is now conducted lend particular interest to another function of industrial research, namely, that of finding new outlets for present products and new products for existing plants. To take an extreme case, no one for example realizes better than the duPonts that the vast new plants which they have constructed for the manufacture of explosives to meet the requirements of the Allies will ultimately, and let us pray it may be soon, find their occupation gone. The sagacious officers of this corporation are therefore already turning their attention to utilization of their plant and special products in the constructive arts of peace. They have begun the manufacture of artificial leather, lacquers, celluloid, picric acid for use in dyeing, heavy chemicals and many individual dyes and intermediates.

In a less acute sense, but no less surely, similar problems confront manufacturers everywhere. They confront you. And their solution in anything but a hit-or-miss and half-way fashion involves intensive industrial research.

In conclusion, let me point out that if the community is to receive the full benefits of industrial research the laboratory must be close to capital and closely in touch with industry. The results of research may long lie dormant and unappreciated unless they are placed effectively before those who are able to make use of them.

Archæological Spoils of War*

An Early Christian Mosaic Discovered in Palestine

THE interesting pavement mosaic, parts of which are illustrated in the accompanying photographs, was discovered after the advance of our troops towards Gaza, in the neighborhood of Shel al, on the Wadi Ghuzze (Wadi of Gaza), about fourteen miles S. S. W. of Gaza, and eighteen miles N. W. of Beersheba. The discoverers were members of the Australian forces. Traces of ruins were observed on a hill or mound in a ravine, and this led to excavation, revealing, at a depth of 3-4 ft., a pavement, evidently covering part of the floor of a church, 20 ft. by 30 ft. in dimensions, and in good preservation, except down the right side, where much has unfortunately been lost. Bones were found, including the skulls of children, apparently upon the surface of the mosaic, suggesting that people who had taken refuge in the church may have been killed by an invading enemy. As the site was exposed to shell-fire, it was first covered up again. Afterwards, the mosaic was carefully taken up and removed to Cairo.

The photographs represent all that remains of the inscription at the top of the pavement, and the central part of the design at the bottom—a vase (flanked by peacocks, not shown), and baskets of grapes with doves. The complete design is a scheme familiar in Early Christian and Byzantine art, a vine rising from a vase, and spreading symmetrically into convolutions in each of which is a bird or animal. About twenty of these convolutions remain in whole or part, and among the creatures which they contain are a lion, ox, sheep, hare, gazelle (?), dog (?), with various birds, including a partridge, in addition to the peacocks and doves already mentioned. The inscription is surrounded by an ornamental border, a feature of which is an intermittent fret pattern, with lines crossing in such a way as to suggest a *Swastika*. The whole design is rich in elements of Early Christian symbolism. The vase and vine have a eucharistic meaning; the peacocks stand for immortality; other birds and animals have their place in the system of symbolic zoology of which the text-books in East and West were known, respectively, as *Physiologus* and *Bestiary*. But it is not advisable to press the symbolism too far; at the date at which the pavement was laid down, artists were wont to graft on the symbolic stem details intended merely for decorative effect. The design is very characteristic of the period between the fourth and seventh centuries after Christ. In the province of mosaic art it occurs both on floors and walls; and a close parallel to the present pavement was discovered in 1894, near the Damascus Gate, at Jerusalem. Another parallel is the well-known mosaic brought by Rennan from Kabr Hiram, and now in the Louvre, at Paris. Mosaic pavements of this kind, mostly with animal ornament, were made in great numbers in all the countries of the South and East Mediterranean littoral; the people of Syria-Palestine were fond of them, and the town of Madaba, N. E. of the Dead Sea, has proved especially rich in remains. A taste for this form of luxury probably spread south into Sinai, where, in such places as Abda and Esbeita, more mosaics should ultimately be found. The inscription, unfortunately imperfect, is in Greek, and states that the Church was built by "our most holy (bishop?) and the God-fearing George" at great cost in the year 622. An adjective giving either the native place of "George" or his official title is badly damaged; of the conjectured word, *episkopos* (bishop) practically nothing remains; it is suggested on the analogy of other inscriptions. The year 622 is in all probability a year of the local era of Gaza, and equivalent to A. D. 561-2. This date accords with the general style of the work, for which the seventh century would be too late. The temptation to identify the "God-fearing George" with the patron saint of England should be steadily resisted. His place in the inscription is secondary; he is mentioned not as a great person, but as an ordinary man; he is probably one who, by purse or by profession, contributed to the erection of the local church.

Electric Properties of Silicon and Germanium

WHEN examining silicon from the Yajee works in Dalmatia, in 1913, Dr. E. Baerwind and Professor F.

*From the *Illustrated London News*.



With a design including a vase, baskets, grapes, and animals; part of a Mosaic pavement unearthed in the advance on Gaza

Fischer observed that silicon possessed the highest thermoelectric power known. Strangely enough, however, the silicon from different sources differed, being sometimes strongly electro-positive against copper, and sometimes negative, and by combining the positive and negative varieties they obtained, in fact, a thermocouple having the extraordinarily high thermoelectric force of 1,000 microvolts per degree Centigrade. There is always a little iron and other impurity in silicon; such impurities seemed to diminish the thermo-force, but not to affect its sign, and the only characteristic difference they could find was that the negative variety seemed to contain a little silicon oxide, or a little more than the positive variety. When resuming these researches recently in order to



"This church was built by our most holy bishop and the God-fearing George"; a Greek inscription, with a swastika border design, in the Mosaic found near Gaza

determine the exact percentage of oxygen in silicon. Fischer and Baerwind found, however, that it was impossible to exclude all oxygen when analyzing their silicon. Compact silicon, they confirm, was indeed not oxidized when heated to 1,100 deg. C. though it turned iridescent; but finely divided silicon was distinctly oxidizable, and as they had to grind their silicon (before dissolving it) in an agate or silicon mortar, and thus to expose constantly fresh hot surfaces to the oxygen of the air, a slight oxidation was unavoidable. They therefore tried to purify the silicon by crystallization from different metals. Dissolved in aluminium and crystallized from this solution, the Si was always highly positive, no matter whether originally positive or negative. Crystallized from silver or from tin, in which

Si is far less soluble, the Si was always negative. Now aluminium would reduce any oxide in the Si, which the silver and tin would not do; but the Si from Al was not free from Al. The specific gravity of the two varieties was the same, 2.33; heating up to 1,200 deg. C. did not change the sign of the thermoelectric force, though heating in a vacuum electric furnace did, and they finally concluded that oxygen is probably responsible, i. e., pure silicon is thermoelectrically positive, but turns negative by being oxidized. Prof. C. Benedicks, of Upsala (*"Jahrbuch für Metallographie,"* 1915, pages 225 to 238; the other researches have appeared in the *Physikalische Zeitschrift* of August 15, 1916, page 373 to 376, and the *Zeitschrift für Anorganische Chemie*, 97, pages 56 to 73, September 12, 1916), had arrived at a different conclusion. Experimenting with germanium, of which he had only a specimen of 0.46 gramme weight (presented by its discoverer, Clemens Winkler) at his disposal, he observed that germanium showed the highest thermoelectric force next to silicon, which he also studied. The germanium was rapidly cooled; white tin he found thermoelectrically negative (weakly), very slowly cooled gray tin strongly positive. Benedicks therefore ascribed the peculiarity to the rate of cooling, which Fischer and Baerwind do not confirm. The two substances also resemble one another in their pronounced rectifying power, which was investigated both by Benedicks and by Fischer and Baerwind. Here, again, the positive and negative variety of silicon differed as to the direction of the rectification. Now thermoelectric force and rectifying power generally go together, but the nature of the rectification is not quite understood. The peculiar behavior of silicon may help to elucidate the phenomena.—*Engineering*.

Cheese as a Meat Substitute

AMERICAN Cheddar cheese is a most satisfactory substitute for meat and may be made the important protein dish of a meal, say food specialists of the United States Department of Agriculture. Too many people use cheese only as an appetizer. Since it compares very favorably with meat in protein content and can be kept and served easily, its wider use is advocated.

Contrary to the opinion of many, Cheddar or "store" cheese is not usually indigestible and constipating. Extensive digestion experiments conducted by the department have demonstrated that more than 95 per cent of the protein in cheese is digested and that 90 per cent of its energy is available. Even when eaten in large quantities and for long periods, no case of indigestion, constipation, or other disturbance was observed in those who ate it. One person who ate cheese as the chief source of protein and energy, eating an average of 9.27 ounces daily for more than two years, did a fair amount of muscular work and kept in good health.

PROTEIN AND ENERGY VALUE OF CHEESE

The value of cheese in comparison with some of the common meats is shown in the following tables:

One pound of American Cheddar cheese contains as much protein as: 1.57 pounds of sirloin steak; 1.35 pounds of round steak; 1.89 pounds of fowl; 1.79 pounds of smoked ham; 1.81 pounds of fresh ham.

To supply energy, also, cheese is one of the best food products. On the basis of energy supplied, one pound of cheese equals: 1.98 pounds of sirloin steak; 2.61 pounds of round steak; 2.52 pounds of fowl; 1.17 pounds of smoked ham; 1.29 pounds of fresh ham.

Thus it is seen that a pound of cheese supplies more than twice as much energy as a pound of fowl or round steak and almost twice as much protein as the same amount of fowl or ham.

Cheese may be used in many palatable dishes. When grated it may be used in soups or with many vegetables. Other foods with which cheese is used are: Macaroni and cheese, Welsh rabbit, tomato rabbit, baked rice and cheese, baked crackers and cheese, vegetable and cheese rolls, cheese omelet, oatmeal and cheese, and cheese mush.

Recipes and further information are given in *Farmer's Bulletin* 487, *Cheese and Its Economical Uses in the Diet*, which may be obtained free on application to the Department of Agriculture, Washington, D. C.—*Weekly News Letter* of the Department of Agriculture.

Fig. 2
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Thermionic Detectors*

In Wireless Telegraphy and Telephony

The arts of wireless telegraphy and telephony involve the use in the receiving circuit of some device named a detector, which is sensitive to electric oscillations of very high frequency. In the earliest years of radiotelegraphy the appliance used was the so-called coherer, in which a small mass of metallic filings, or an imperfect contact between two pieces of metal was converted into a better conductor by the passage through it of the high-frequency oscillations. All the various forms of coherer have now been abandoned and are no longer used as detectors. In modern radiotelegraphy, so far as regards the spark or damped-wave system, only three types of detector are at present in practical use. The first of these is the magnetic detector, chiefly the rotating band form, invented by Marconi; the second type is some form of rectifying contact or crystal, such as the carborundum detector due to Dunwoody, or the zincite-chalcopryrite rectifier of Pickard; and the third is some modification of the thermionic detector, or Fleming oscillation valve.

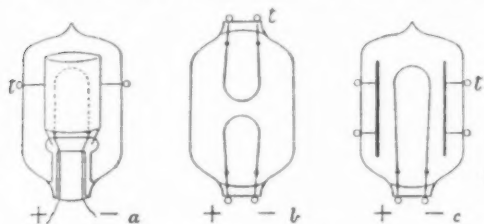


Fig. 1—Various forms of Fleming oscillation valve or thermionic detector used in wireless telegraphy

In the magnetic detector the electric oscillations to be detected are caused to circulate round a magnetized iron wire and alter its magnetic permeability or hysteresis in such a fashion as to create a sudden change in the magnetization of the iron. This in turn is made to create an induced electric current in a second coil and reveal itself by a sound made in a telephone in series with that coil. The rectifying contacts or crystals depend upon the fact that a contact of small surface between certain substances, generally crystalline, has a greater electric conductivity in one direction than in the other. Hence if such a contact as that, for example, between a fragment of zincite or native oxide of zinc and a piece of chalcopryrite or copper pyrites is traversed by a train of electric oscillations, these will be converted into a movement of electricity chiefly in one direction. Accordingly, if a rapid sequence of such oscillations passes through such rectifying contact placed in series with a telephone receiver, the latter will be traversed by a series of intermittent gushes of electricity in the same direction, and will emit a sound the pitch of which is determined by the group frequency of the oscillations. A very commonly used rectifying contact is a crystal of carborundum, or carbide of silicon, held between metal clips. Although this rectifying property of certain contacts and crystals has been much studied, the reasons for it are not yet fully elucidated, but it is probably connected with the thermoelectric properties of the materials.

The third type of detector is the thermionic detector first suggested and used by Dr. J. A. Fleming, of University College, London. The construction and mode of operation of this form of detector may be briefly described as follows: It had been known for many years prior

to the advent of radiotelegraphy that the electric conductivity of a highly rarefied gas was greatly determined by the temperature of the negative electrode by which the current left the exhausted vessel containing it. It had been found by Hittorf and also by Elster and Geitel that if the negative electrode was a platinum wire which could be rendered incandescent, the conductivity of the highly rarefied gas was greatly increased. The emission of positive and of negative ions from incandescent solids *in vacuo* had been studied particularly by Elster and Geitel, beginning in 1880.

In 1884 Edison made known an interesting fact connected with carbon-filament glow-lamps. He sealed into the bulb of one of his bamboo-filament lamps a metal plate placed between the legs of the horseshoe-shaped filament, the said plate being carried on a platinum wire sealed through the glass bulb. He found that when the filament was rendered incandescent by a continuous current, a galvanometer connected between the terminal of the plate and the external negative terminal of the filament indicated no current, but that if connected between the plate and the positive filament terminal, it showed a current of a few milliamperes. Edison gave no explanation of this, nor did he make any application of the discovery. He supplied a certain number of lamps made with middle plates to the late Sir William Preece, and the latter communicated to the Royal Society in 1885 a paper describing various experiments with these lamps. This "Edison effect" was more completely examined by Dr. J. A. Fleming in researches described by him in papers to the Royal Society in 1890 and to the Physical Society in 1896. Dr. Fleming showed that the effect was in some way due to the scattering of particles charged with negative electricity from the hot filament, and that it could be prevented by enclosing the negative leg of the carbon in a glass tube, or placing a sheet of mica between the carbon and the plate. He also proved, as Elster and Geitel had done in another way, that a vacuum tube having two carbon filaments as electrodes had a very large conductivity for small voltages when the negative electrode was made incandescent.

It was not until 1899, when Sir J. J. Thomson announced his epoch-making discovery of electrons, or corpuscles smaller than atoms, carrying a negative charge, that it was clearly recognized that incandescent solids in high vacua emit electric ions, some positive and some negative.

This electronic emission from hot bodies has been very fully investigated by Prof. O. W. Richardson, who has collected most of the known facts in an excellent manual on the subject. None of the investigators of this subject made any practical application of this knowledge until it occurred to Dr. Fleming in 1904 to employ an incandescent electric lamp having one or more plates or cylinders of metal sealed into the bulb as a means of detecting high-frequency electric oscillations, as used in radiotelegraphy. Accordingly he constructed such electric glow-lamps with carbon filaments and a metal plate or cylinder surrounding, but not touching, the filament, the said cylinder being attached to a platinum wire sealed through the bulb (see Fig. 1). He employed this device as follows: The carbon filament in the lamp O (see Fig. 2) is rendered incandescent by a suitable battery of storage cells, B; most usually a 12-volt or 4-volt filament is employed. A circuit is formed external to the bulb by connecting the metal plate or cylinder to the negative terminal of the lamp. In this circuit is placed a current-detecting instrument, such as a galvanometer, G, or a telephone. In the circuit is also inserted the secondary circuit of an oscillation transformer, P, S, the terminals of which are closed by a condenser, C (see Fig. 2).

If electric oscillations are created in the above circuit, the alternations of current are rectified; that is to say, a unidirectional current flows through the galvanometer or telephone. The highly vacuous space between the incandescent filament and the metal cylinder inside the bulb possesses a unilateral conductivity. When the filament is at a very high temperature negative electricity can pass from the filament to the plate, but not in the opposite direction. Hence the device acts as a valve and was called by Dr. Fleming an oscillation valve. Another way of viewing the effect is as follows: When the electric oscillations take place through the condenser, the plate or cylinder in the bulb tends to become charged alternately positive and negative. The incandescent filament is continuously emitting negative ions or electrons, and these at once discharge any positive charge on the metal plate, whereas they do not discharge a negative charge. There is, therefore, a continuous move-

ment of positive electricity to the plate from outside the lamp. If the electric oscillations are in trains of damped groups, then the effect is to convert them into gushes of electricity in one direction which pass through the telephone. If these groups come at the rate of several hundred per second the telephone receiver emits a continuous sound of corresponding pitch, and if the groups are cut up into Morse signals at the sending end, the listener at the telephone hears these signals as long and short sounds.

An electric incandescent lamp with metal plates, grids, or cylinders in the bulb is now called a thermionic detector, because it serves to rectify and render detectable by a galvanometer or telephone receiver the feeble electric oscillations used in wireless telegraphy or telephony. It depends for its action upon the emission by the incan-

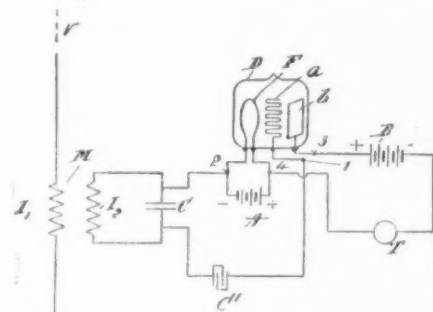


Fig. 3—De Forest audion or form of thermionic detector. D, bulb of glow-lamp; F, incandescent filament; G, grid; P, plate; T, telephone; A, B, batteries; C, C', condensers

descent filament of electrons, or thermions as they are termed.

Dr. Fleming found that a tungsten filament was of special utility for this purpose. The thermionic receiver has great advantages in that it is not injured or put out of adjustment, like crystal detectors, by powerful electric oscillations or atmospheric discharges acting on its receiving circuits.

In some of Dr. Fleming's experiments he employed an incandescent lamp with two plates sealed into the bulb carried on separate terminals. An illustration of such a double-anode or two-element valve was given by him in a paper published in the Proceedings of the Royal Society early in 1905 (see c, Fig. 1). The new thermionic detector naturally attracted the attention of radiotelegraphists, and amongst others of Dr. Lee de Forest in the United States. After adopting the detector in substantially the same form, Dr. de Forest patented in 1907 a modification in which the two metal electrodes were sealed into the vacuous bulb, in addition to the metallic or carbon filament to be rendered incandescent. One of these electrodes was in the form of a plate, and the other of a grid or zigzag of wire interposed between the filament and the plate. In using this double-plate thermionic detector, Dr. de Forest connected the grid terminal to one side of the receiving circuit condenser, and the negative terminal of the filament to the other side of the same condenser; but, instead of inserting the telephone or current-detecting instrument in this grid circuit, he included it in a separate external circuit connecting the plate with the filament, and placed in this circuit also a battery with negative pole connected to the filament (see Fig. 3).

Dr. de Forest called this arrangement an *audion*, and maintained that the physical action was different from that of the Fleming valve, though valves with two anode

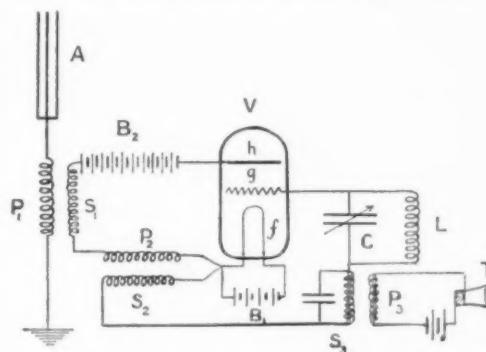


Fig. 4—Mode of using double-anode valve or thermionic detector as a generator for electric oscillations

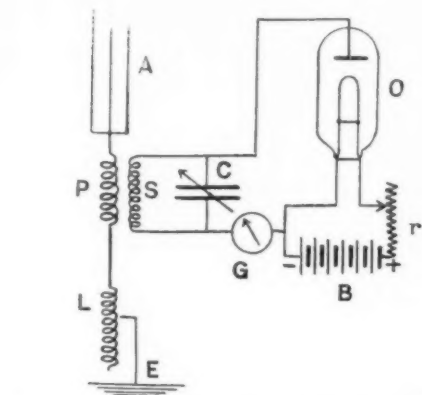


Fig. 2—One mode of employing the oscillation valve as a detector in a radiotelegraphic receiving circuit. A, antenna; P, S, oscillation transformer; C, condenser; O, oscillation valve; B, battery; G, current-detecting instrument

* From Nature.

plates had already been in use for certain experiments. It has been shown, however, to be essentially the same. It is clear that the performance of the audion as a radio-telegraphic detector depends entirely upon the thermionic emission from the incandescent filament. It has been demonstrated by Dr. E. H. Armstrong in a paper in the Proceedings of the Institute of Radio-Engineers for September, 1915, that the physical actions taking place in the grid circuit of Dr. de Forest's audion are precisely the same as in those in the Fleming valve.

The thermionic emission of negative ions causes the grid to become negatively charged. On the other hand, the battery in the external circuit connected to the plate sends a thermionic current through the vacuum space between the filament and the plate inside the bulb, in virtue of the incandescence of the filament or negative electrode. This current flows also through the telephone or current-detecting appliance. When the grid becomes negatively charged, due to the rectification of electric oscillations impressed upon the grid circuit, it reduces the thermionic current flowing between the filament and the plate, and therefore varies the current through the telephone. The physical actions which contribute to the operation are therefore, all dependent upon the thermionic emission from the filament and upon the increased unilateral conductivity of a highly rarefied gas or vacuum space when the cathode or negative electrode is rendered incandescent.

Ship Trials Relation to Sea Speed

WHILE it is generally admitted that the speed attained by a steamer on a trial trip has very little relevance to her performance on service, all owners have not abolished the successful trial trip as part-basis of their contract with the builders. Merchant ships in the majority of cases go on trial loaded in a manner which does not even approximate to their average condition on service, and the most useful function performed in that of testing the boilers and engines. The speed obtained by a vessel run on a measured mile gives the owner only an indication of what may be expected at sea, but the trial is helpful to the builder, as it provides useful data for the performance of other ships running under similar conditions.

RESISTANCE AT SEA

It is well known that the resistance of a ship in a sea-way is much greater than the resistance in smooth water for the same speed. Among waves the ship rolls and pitches, and pitching is very productive of increased resistance. The amount set up will largely depend upon the size of the vessel; waves which would cause violent motion in small steamers have little effect on large liners. On the whole, the waves set up irregularities in the resistance and in consequence the speed alters, a good deal of resistance being used up by the acceleration produced. The skin friction resistance is also increased since greater bodies of water have to be set in motion. Nor is this all; the pitching may render it advisable not to run the propellers at full speed, on account of the danger from racing, and in any case the disturbance of the water decreases the propeller efficiency.

On trial, again, a vessel will be running with a clean bottom, an ideal condition which cannot be regularly maintained with a ship in commission, and a small amount of fouling is sufficient to cause an appreciable increase of the skin friction. In experiments with different kinds of surfaces Mr. W. Froude found that rough surfaces have nearly twice as much resistance as smooth, hard surfaces. Should a vessel be allowed to get her bottom very foul the increase in the skin resistance may be even greater. As a rule—at least in vessels frequently in home ports—great care is taken to maintain the bottom clean, but even in the temperate zones a ship left for, say, six months might easily have her skin friction increased by one-third. This would be a very serious matter in slow and moderate speed vessels, such as tramps, intermediate liners, and the majority of first-class passenger steamers, as the frictional resistance would never be much less than 70 per cent of the total. If it should be the practice to measure the fouling of the bottom by noticeable loss of speed, it may well be that considerable loss of power would be taking place before the discovery was made. In a moderate speed vessel the resistance due to skin friction might be doubled with the loss of only about two knots in speed. There is still another difference between trial runs and sea voyages: in the former the boilers are clean, and remain so throughout the short period of the trial, whereas at sea a certain definite loss must be put up with as the boiler tubes become dirty.

PITCHING AND FORM

The fact that pitching causes so much loss in speed has resulted in the adoption of numerous expedients where-

This action is not necessarily dependent upon the presence of any residual gas in the bulb, because even in a highly perfect vacuum the electronic emission from the incandescent filament would take place.

The double-anode Fleming valve, or the valve with grid and plate, called an audion, has the property that an amplification of current variation can be produced by it.

Thus, if the grid-plate thermionic detector is arranged as in Fig. 3, feeble electric oscillations taking place in the grid external circuit can be made to produce large variations in the continuous current flowing in the external plate circuit.

Moreover, by connecting two or more such double-anode thermionic detectors in series, the current in the plate circuit of one, acting inductively on the grid circuit of the next, enables a double amplification to be produced.

Furthermore, such double-anode thermionic valves can be used as generators of electric oscillations by inductively connecting through a suitable transformer the grid and plate circuits *g* and *h* of one and the same bulb *V* (see Fig. 4). The arrangement then acts as follows: Feeble electric oscillations set up in the external plate circuit by any means create induced oscillations in the grid circuit, and the latter sustain and enhance the former, the energy to create these enhanced oscillations coming from the battery in the plate circuit.

The process exactly resembles that in which a Bell

by it may be reduced. Practically all seamen favor full lines forward, and to a less degree aft, as being effective in this direction, whereas in a smooth-water trial a full middle body with fine ends is advantageous for easy driving. All model tank experiments show great advantages for full 'midship sections and parallel middle body in practically all merchant vessels, and these advantages are found on the smooth-water trial trip. It is, however, generally admitted that speed in rough water will be more easily maintained with a fine 'midship section.

With the object of determining the effect upon resistance due to the pitching caused by the waves, Mr. R. E. Froude carried out some experiments on the resistance of models running in water which was artificially agitated to give a wave formation. The experiments represented the ship steaming against a regular head sea; the models were ballasted so that their trim was correct and the distribution of weight proportional to that of the ship. The results of the increase of resistance were plotted for a given speed to a base of wave period. The resistance had a very marked maximum. The period of the wave corresponding to the greatest resistance exceeded that of the pitching period of the ship, and the largest waves more than doubled the resistance of the model over that for smooth water, while a difference in wave period of 15 per cent either way from that of the ship caused the increase for resistance to be half as much again as that for smooth water. Among waves differences in resistance due to small variation in forms were found in every case, but they were much less than the differences due to the variation of the longitudinal distribution of weight. Perhaps the most interesting result of the experiments, and, in fact, the reason for which they were undertaken, was the difference between hollow and straight water-lines forward. In smooth water the resistance of the straight-lined model was greater than that of the model with hollow lines, but the increase of resistance in the waves above that for smooth water was greater in the hollow than in the straight-lined model.

SEA SPEEDS AND DESIGN

Whatever be the reasons for the increased resistance of ships in a sea-way, it is quite certain that sea speeds of vessels form valuable guides to future designs, and it is perhaps remarkable to find so little variation of speed from the average as is recorded in ships' logs. The advantage of technical advice to the ship-owner in this respect is obvious, and some shipping companies do not trouble themselves about trial trips on the measured mile, being content merely to specify the attainment of a certain horse-power by the machinery. From the service results of their other ships they are then able to estimate what the sea performance of the new vessel is likely to be, and it is on this speed that schedules are drawn up, and not on trial speeds. The owners' technical advisers are not only able to arrive at the horse-power necessary for a certain sea speed, but in addition they know the average draught and displacement at which the ship will usually run when in service.

Vessels intended for service in shallow water generally require a different form of hull and a different type of propeller from those running in deep water. It will often be the case that the shallow water vessels have their trial runs in deep water when a certain speed has to be attained, and the form and propellers designed to obtain good

telephone receiver in circuit with a battery and carbon microphone transmitter emits a continuous musical note when the diaphragm of the receiver is held near that of the transmitter. Feeble vibrations are set up in the microphone diaphragm by noises in the room, and these vary the current through the telephone receiver, and the sound so emitted keeps the transmitter diaphragm in motion.

Again, the double-anode valve can be used as a telephonic relay in ordinary telephony to magnify and repeat sounds.

The oscillation valve is not simply a detector; it is a quantitative detector, and hence has been extensively used as a receiver in all experiments in wireless telephony. In fact, most of the successful long-distance experiments in radiotelephony have been conducted by it. For when so used it rectifies the continuous high-frequency oscillations in the receiving circuit into a direct current. Hence the variations in amplitude in these oscillations which are produced by the microphone in the transmitter circuits make themselves evident as variations in the rectified current which flows through the telephone receiver, and these reproduce the sounds of the speech made to the microphone in the transmitter. This thermionic detector promises, therefore, to be of great use in the solution of the problem of radiotelephony, as well as that of repeating or relaying ordinary telephonic currents.

results on the deep water trial will not necessarily be the best for the ship in service in shallow water.—*London Times Engineering Supplement.*

Black Thread Disease

INVESTIGATIONS on the "black thread" disease of *Hevea* in Burma by the Board of Scientific Advice for India indicate that the disease first breaks out soon after the rains begin and completely disappears after the close of the monsoon. It is not fatal to the tree but does much damage by attacking the tapped area of the bark. Infected areas do not yield latex and severely diseased trees have to be excluded from the tapping round. In 1914 the loss of rubber on one estate was 2-3,000 lbs and in 1915, 8-9,000 lbs., there being 12,000 trees affected in 1914 and 42,000 in 1915, out of 77,000 in tapping. The cut surface of the tapped bark becomes marked by vertical cracks, from which latex, occasionally exudes; sometimes a thick cushion of coagulated latex forms below the renewing bark, causing the latter to bulge out and ultimately fall off, so as to leave an open wound. The renewal of the bark is irregular, masses of callus appear on the cut surface and further tapping is hindered.

The cause of this damage is a species of *Phytophthora*, differing from the well-known canker fungus, *Phytophthora Faberi*, to which it had been attributed in the Dutch Indies. It seems to occur in Ceylon also but has been there supposed to result from climatic conditions. In South India the same fungus is believed to be responsible for considerable damage and is at present under study by the Madras Department.

The fungus is found both in the diseased bark and also on the fruits. It has been grown in pure culture and an extensive series of inoculations carried out both on rubber and on numerous other plants known to be attacked by species of *Phytophthora*. On rubber it is a wound parasite, being unable to infect the undamaged bark; through wounds it infects readily and produces the characteristic symptoms of the disease. Of the other plants tried, the ordinary hosts of *Phytophthora infestans*, *Ph. parasitica* and *Ph. Colocasiae*, the three species most commonly found in Northern India, are immune, as also is cacao, one of the chief hosts of *Ph. Faberi*, and many other plants known to be liable to *Phytophthora* attack. Only on seedlings of the garden plants, *Gilia* and *Salpiglossus*, were successful infection secured.

The disease is favored by excessive humidity and shade and is, therefore, worst in thickly planted rubber estates. The free admission of sunlight and air checks its progress, and good results may be obtained from judicious pruning and thinning. The chief source of infection seems to be the fruits, and as these have practically no value and develop in the rains a copious growth of the parasite, from which spores are shed on the bark, it is recommended that all fruits be carefully picked and destroyed before the monsoon breaks, in infected plantations.

In continuation of the studies on allied species of this genus which have been carried on at Pusa in recent years, an account of a form of *Phytophthora parasitica* found on *Vinca rosea* has been recently submitted for publication. Germination of the durable type of spore (the oospore) has been obtained and was found to correspond in essentials with that described for *Ph. erythroseptica* in Ireland.—Annual Report of the Board of Scientific Advice for India.

The Early History of the Theory of Eccentrics and Epicycles*

By Noel Sargent

BEFORE undertaking our investigation we must know clearly just what we shall mean by the terms Eccentrics and Epicycles.

An *Eccentric* circle was the orbit which the object under discussion (usually the sun and moon were the objects in eccentric theories) was supposed to describe about the earth. It was conceived *Eccentric* with the earth, that is the fixed earth is not quite at the center of the orbital circle, which is also called the deferent. The idea of *Eccentrics* was adopted to explain the unequal motions of the sun and moon.

An *Epicycle* in ancient astronomy was a little circle having its center on the circumference of a greater one; or a small orb or sphere, which being fixed on the deferent of a planet, is carried along with it, and yet, by its own peculiar motion, carries the planet fastened to it round its proper center. That is, the centers of the epicycles move around the circumference of the deferent. It was by means of epicycles that Ptolemy and his followers solved the various phenomena of the planets, but more especially their stations and retrogradations. The large circle, called the deferent, had the earth as its center. It will be noted that in both the eccentric and epicycle theories the earth is held to be fixed.

It can be easily seen that this system was in a geometrical sense defensible. It harmonized fairly well with appearances. To the ignorant it recommended itself because of its conformity to crude common sense; to the learned, by the wealth of ingenuity expended in bringing it to perfection.

A study of the early history of eccentrics and epicycles naturally involves a study of the theories which led up to the fuller developments.

So far as can be ascertained the Chinese and Chaldean astronomy held no mention of any theories regarding the revolution of the earth or planets.

The Egyptians supposed Mercury and Venus to revolve around the sun and be carried with him in his annual motion around the earth. It will be recognized that this is a forerunner of the epicyclic idea. There is no direct evidence that any of the Greek astronomers knew of the Egyptian ideas, though it is certain that Copernicus was aware of the Egyptian system.

Little definiteness is known of Greek astronomy until the school of Pythagoras in the sixth century B. C. The exact views of Pythagoras himself do not seem to be known, as he committed nothing to writing. We find one writer (Moulton) saying that "Pythagoras believed that the earth is round, but that it is immovable and at the center of the universe." Other writers hold that, while this was what Pythagoras outwardly proclaimed, to the members of his own school he proclaimed his real views on the subject. Thus Routledge asserts: "Pythagoras taught his disciples something very like the astronomy which places the sun in the center of our system, and recognizes the fixed stars as suns which are the centers of other systems."

But it is in Philolaus that we find the first real forerunner of the heliocentric theory finally evolved in 1531 by Copernicus. Philolaus was a pupil of Pythagoras and was the first to coordinate and put in concrete form the ideas of his teacher. Though the ideas of Pythagoras himself are uncertain, the great body of the Ionian school is known to have considered the earth as the center of our system; Philolaus, on the contrary, asserted that the sun was the center of the system, though at the same time evolving a fantastic theory of Jupiter or Zeus as the real center of the universal system and of a counter-earth. There are, said Philolaus, two motions of the earth: (1) a diurnal movement on itself; and (2) an annual movement around the sun.

His theory was not based on any extensive investigation or observations; we should not expect to find it so. It was rather an astronomical hypothesis, based in large measure on a further application of the fantastic numerical system or theory of the Pythagorean school. Philolaus, for instance, held that the earth was not worthy of being the center of our universe, and that as the light came from the sun and "Fire is more worthy than earth," that, ergo, the sun was the center. Purely an imaginative theory, having little or no vogue during his period or following him, though Aristotle comments on it, we must accord to Philolaus the distinction of being the first to formulate the heliocentric theory.

Heracleides, another of Pythagoras' pupils, taught that the sun, while circulating round the earth, was the center of revolution to Venus and Mercury—exactly the Egyptian view.

Of such speculations Socrates believed, according to

Xenophon, that "the speculators on the universe and on the laws of the heavenly bodies were no better than madmen." (Lewis, *Historical Survey of the Astronomy of the Ancients*, p. 113.)

It was Plato, pupil of Socrates, who proposed the problem which occupied Greek astronomers from that time:—the problem of representing the courses of the planets by circular and uniform motions.

This was so since after the Pythagorean school Greek astronomy became less purely speculative and more scientific. Eudoxus (409–336 B. C.) presented the first mathematical theory of celestial appearances. He tried to construct a theory of celestial motions out of uniform circular motions which should agree with observations. He imagined the fixed stars to be on a vault of heaven; and the sun, moon and planets to be upon similar vaults or spheres, 26 revolving spheres in all, the motion of each planet being resolved into its components, and a separate sphere being assigned for each component motion. Callippus (330) increased the number of spheres to 33. The real existence of the spheres was not suggested, but the idea was only a mathematical conception to facilitate the construction of tables for predicting the places of the heavenly bodies.

Aristotle (384–322 B. C.) held that the earth did not move. He advanced the very conclusive argument against its revolution that there were no apparent displacements of the stars such as should result from such motion. He denied that the earth can revolve, either in the center of the world or about the center, because such a motion would necessarily be violent—that is, against the nature of the earth. "The order of the world is eternal, and therefore no violent or contra-natural motion can have a place in this order." The earth was fixed in the center of the universe. The other heavenly bodies were thought to have uniform circular motions.

THE ALEXANDRIAN SCHOOL

The last period of Greek astronomy is that of the Alexandrian school, founded at Alexandria by Alexander the Great.

Aristillus and Timocharis, early members of this school, set up instruments and fixed the positions of the zodiacal stars, near which all the planets in their orbits pass, thus facilitating the determination of planetary motions.

Aristarchus was the first great astronomer of this school (fl. 275 B. C.). He developed a genuine heliocentric system which was described by Archimedes in his "Arenarius," only to be set aside with disapproval. Aristarchus, to explain his system a little more fully, held that the earth rotates and revolves. He overcame the objection of Aristotle by supposing that the fixed stars are indefinitely remote. The earth's orbit would be a mere point in comparison. The sun was stationary and it was round it that the earth revolved.

Apollonius (latter part of third century B. C.) started a new era by proposing to consider the motions of the heavenly bodies as being purely geometrical. He used the epicycle and deferent to explain the retrograde motions of the planets. He did not, however, make much progress in applying his ideas.

Hipparchus (180–110 B. C.), perhaps the greatest astronomer of antiquity, employed a geometric scheme of eccentrics and epicycles to represent the motions of the heavenly bodies. Having measured the unequal motions of the sun and the moon, he allowed for this by supposing that the center, about which the sun moves uniformly, is situated a little distance from the fixed earth. He called this center the *excentric*. The line from the earth to the *excentric* was called the line of *apses*. A circle having this center was called the *equant*.

Ptolemy (100–170 A. D.) was the first great astronomer of note after Hipparchus and the last great astronomer of the Alexandrian period. From his time to that of Copernicus not a single important advance was made in the science of astronomy. Ptolemy's ideas were set forth in his work, "the Almagest." He put the theories of eccentrics and epicycles in their most advanced form. He adopted the *excentric* and *equant* of Hipparchus to explain the unequal motions of the sun and moon, and the epicycles and deferents of Apollonius to explain the retrograde motions of the planets. Ptolemy made improvements upon these ideas but kept their essential features. When new inequalities were brought to the attention of Ptolemy or his followers they were explained away by the addition of new epicycle—really geometrical makeshifts.

After Ptolemy astronomy was cultivated only by the Arabs until about the sixteenth century when Copernicus brought forth his system. No new discoveries were made by the Arabs, who simply kept on finding more and more accurate values for the constants involved in the Ptolemaic system.

Enlargement of the Sun at Sunset

W. F. Badgley

Most people have looked through a telescope or binoculars and need not be told that the things that they saw enlarged by the glasses were not changed in size by their looking at them, nor moved farther apart.

It is so with the enlarged sun at sunset; it only appears changed because the air magnifies it, and measured with any telescopic instrument its width is not altered.

If you have a reading glass, put it on a sheet of ruled or printed paper and you will see that it does not magnify at the middle, but does so towards the edge, and that the magnification is greater in line with the edge, and not towards the center, and that near the edge a circle becomes an oval.

The scientific explanation of the apparent enlargement of the sun is, that when it is seen high up there is nothing near it to compare it with in distance, so we believe it to be near and therefore small; but when we see it on the horizon which we know to be far away, we believe it far and therefore deceive ourselves, and believe it large.

If you are happily a dweller in the country, and get a change of seeing the sun or moon, when near the horizon, through the branches of trees a hundred or so yards away, the orb will appear as though just at the back of the network of branches; or if you will look at the moon, when low down, through a lace window curtain, it will seem to be just beyond the lace; and whether seen through, or away from, the trees or curtain, there is not a bit of difference in the size of the orbs. This disposes of the scientific deceitful comparison idea.

The sun as it nears the horizon and appears enlarged usually becomes an oval longer in breadth than in height, because it is seen through the edge of an aerial lens. The air, to a small height, is in a condition to magnify objects and has been so all day, but looking upwards its thin layer would have little effect, where as looking through it toward the horizon, the effect would be increased about sixteen times by the increased depth of air looked through.

It is not always that the air acts to enlarge objects on the horizon, for one day it may do so and the next day not. The effect is due to some particular state of the air. It cannot be due to water vapor for the quantity in the air at any season does not change much from day to day. Neither is it due to foginess in the air, for the sun or the moon seen through fog, or thin cloud, is a pale thing not the least enlarged while if enlarged the sun is usually fiery red and the moon sometimes green.

Dust and heated air appear to be the only possible causes of the magnification. Summer and autumn are the usual times for seeing the phenomenon, because they are dusty times; we do not see it in winter, or if we do, can account for it by smoke dust. Objects seen through dusty air are enlarged and reddened. But in all these cases the air may be heated.

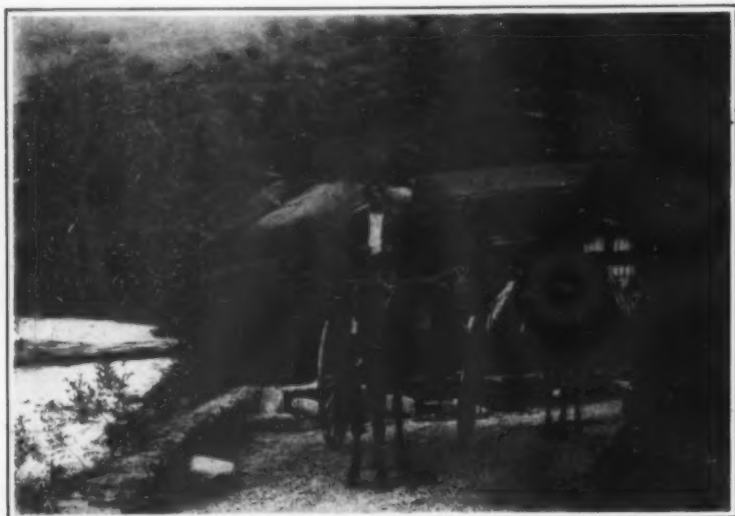
Objects seen through the heated air of deserts are enlarged; seen through smoke from a chimney, they are enlarged. But in both these cases the air is certainly dusty.

So there is something still left in this enquiry for clever people to find out. On one occasion, being near the western edge of the plateau three hundred feet above the plain to the west, the sun set on a clear horizon and was not enlarged; while to the east, across the plateau, the full moon rose enlarged through a reddish mist which had a height of about twenty degrees above the horizon. While in the mist the moon was of a bright green color and had a duller green halo; on leaving the mist it took on its usual size and yellowish silvery look, and had no halo. The change was sudden as the mist had a very definite edge.—*Popular Astronomy*.

Analyzing Ferrosilicon Without A Platinum Crucible

It is possible to dispense with expensive platinum crucibles in analyzing ferrosilicon, according to Dr. Herwig in an article in *Stahl und Eisen*. According to a translation in the *London Iron and Coal Trades Review* iron crucibles can be used if instead of the usual carbonate of soda and potash method sodium dioxide is used in the ignition mixture. Great care must be taken to reduce the ferrosilicon to as fine a powder as possible, to remove all coarse particles and to mix the powdered silicon thoroughly and very uniformly with the dioxide, as otherwise dangerous ebullition might take place, which would nearly empty the crucible and the spattering endanger the analyst's eyes. The author gives a comparative list of 22 analyses made, one-half of these by the sulphate, the other half by the dioxide method, of ferrosilicons, ranging in silicon content between 10.75 and 90.78 per cent. The differences in the results obtained by the two methods range only between, say, plus 0.05 and minus 0.13 per cent.—*Iron Age*.

*Popular Astronomy.



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Muleteer taking a cargo of fruit to Bayonne



Peasants arriving at the market with the fruit

The Cherry Crop of France

New Methods and Uses That Would Prevent Losses

ONE of the largest fruit crops in France, that of cherries, has hitherto been chiefly used in the fresh state or for making preserves, though in a few provinces the fruit has been either distilled or preserved in brandy or maraschino. The difficulties caused by the war with regard to transportation and manual labor, however, have resulted in a heavy loss, great quantities of the cherries drying on the trees or rotting on the ground. It is possible to remedy these losses by instructing orchard-owners in simple methods of producing sugar, wine, and alcohol from cherries.

The large black saccharine varieties are gathered when dead ripe and heaped in wooden vessels where they are allowed to stand for 24 hours before being put through a crusher, seeds and all. The vat containing the crushed mass is then put in a cool place for three or four days, the contents being stirred at intervals with a wooden fork or paddle. The juice is then filtered off through several thicknesses of cloth and the residue put through a press. This is then either distilled, or treated with water to obtain a second yield of juice, which is added to the first, the whole being then boiled down to about half the quantity. During the boiling it must be constantly stirred to prevent its sticking to the bottom and being caramelized.

The reduced juice is strained through a thick cloth into casks, preferably those which have held red wine and which have been previously thoroughly treated with sulphur fumes. These are then sealed and left in a cool place for a year. At the end of this time the clarified cherry juice is ready for consumption; it is sweet, sometimes even quite saccharine, and agreeably aromatic, and furnishes a much appreciated delicacy, capable of providing a substitute for table wines at small expense.

Cherry juice can also be utilized to make an alcoholic drink offering nearly all the advantages of wine, if we can believe German gastronomists. To prepare this 500 grammes of bitter almonds are first pounded in a mortar and the resulting paste diluted with a liter of water in which 300 grammes of dried cherries have been previously boiled.

Into this are then poured 1.0 liters of cherry juice and 1.5 liters of good brandy, or in default of this, 2.0 liters of good white wine; an aromatic quality is given by the addition of 40 grammes of cinnamon, 25 grammes of cloves, and 10 grammes of cardamom; finally, 2 kilogrammes of sugar are dissolved in the liquor, which is, by the way, too large an amount for this cherry-wine (Kirschenwein) to keep very long. It is stirred 5 or 6 times during the course of the next 24 hours and then stored in well sulphured casks, to be drunk during the first warm days of spring.

Finally, cherries are the raw material of kirsch, that specially flavored brandy which the peasants of the Black Forest produce in important quantities. Nothing is simpler than its manufacture. The cherries are gathered very ripe and those which are damaged, rotten, or imperfect carefully sorted out; they are then crushed in a vat, a suitable quantity of the crushed seeds being added to increase the aroma, together with sugar, if necessary, and allowed to ferment for 12 to 15 days. When carbon dioxide ceases to be evolved the pulp is carried to the still, where it is constantly stirred until it begins to boil.

While it must be admitted that our cherry brandies are inferior to those made in the Black Forest with fruit of the Herz and Weichsel varieties, which have been highly improved by cultivation, yet French producers can, if they will, easily obtain a very satisfactory kirsch from native varieties—and one infinitely better from the hygienic point of view, than the "kirsch fantaisies" of commerce, which are nothing but frightful mixtures of industrial alcohol and a complex chemical product.

As shown in our pictures, taken at Hoxou (Lower Pyrenees) the Basques also gather large quantities of cherries which they send to various concentration centers (Bordeaux, Marseilles, Toulouse, Paris, etc.).

There is an evident economic advantage in seeking various methods of preserving this fruit, which in good years is produced in abundance too great to be absorbed by the city markets. According to statistics



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Most of the cherry picking is done by the women

more than 20 million kilogrammes of cherries are annually lost in France and this year, when the means of transportation remaining at the service of the public are not sufficient to permit the rapid moving of a heavy yield, 45 to 50 millions loss is to be computed. Such a source of revenue should not be neglected in war times.

Eccentricities of Spelling*

By F. Horace Teall

ORTHOGRAPHY is strictly our name for correct spelling; but, as correctness differs so much according to various standards, orthography is used to name spelling in general. Thus it is only a relative correctness that can

*The Inland Printer.

be asserted for any so-called system. The various systems are known by the names of dictionaries, or as those of dictionary authors or editors.

We find, if we indulge in research, that spelling was supposed to be regulated (at least for his time) by Dr. Samuel Johnson in his dictionary, and that work became the authority of highest resort. Johnson, however, had not made a record that could long stand as the best, because it was replete with eccentric inconsistencies that found temporary support only because they were his. Yet, while this is positive fact, though told here regretfully without detail, Johnson certainly was a great literary scholar, and it has been said that "he first brought order out of the chaos of the language."

Many scholars had preceded Johnson in desiderating a more consistent spelling, and many more have followed him. Just now we are interested in their eccentricities only, not in the vast amount of their true consistency and system. We have always had much of eccentricity, and always shall have. It is apparently impossible to avoid it. Johnson was the most famous lexicographer because of his literary plan rather than his orthographic accomplishment. It was rather in spite of his bad spelling that his work secured vogue. And it would not be hard to prove that each spelling system—as Webster, Worcester, Century, Standard—contains forms that enter it as personal choice, therefore eccentric as judged by other orthographic arbiters.

British authorities are exempted from our inquiries because they practically all agree on the words most open to differences. It is universally known that when British spelling is to be used we are to spell words like travelled, worshipping, etc., with the double consonant, cyclopædia, mediæval, etc., with æ and not the single letter e, and some other settled differences. What little there is additional to these fixed differences must be specially ordered. And that is little only by comparison to the whole, for the British have many practically arbitrary preferences.

Our first American lexicographer was Noah Webster, who recognized the great worth of Johnson's stated plan of definition, but subverted his scheme of spelling. Webster's original work in this line was strikingly similar to the present effort for so-called simplified spelling, being the first authoritative record that gave traveled, worshiped, etc., with only one consonant, and many other changes that have become permanent, but also many that made no headway at all.

Very soon after Webster's death his dictionary was remade by his son-in-law, Chauncey A. Goodrich, who restored many older spellings. Another new remaking, issued in 1864, was edited by Noah Porter, and this became the widely accepted Webster Unabridged, probably more recognized even now than either of its two successors as the record that is meant when we speak of "Webster spelling." Still another edition was made with Noah Porter as editor, first appearing in 1890. This was called "Webster's International." It made more changes in its spelling. Then in 1909 came another remaking, the "Webster's New International," with many startling reversions to older spellings, especially the restoration of the ligatured æ and œ instead of plain e, particularly in medical words. This was largely decided by the general editor, Mr. F. Sturges Allen.



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A specimen of French cherry blossoms



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Filling pans with cherries for shipment

All of this by way of leading to the fact that "Webster spelling" now means something very different from what the name long denoted, and even what it is still commonly thought to denote.

Joseph E. Worcester made his dictionary while the scholarly world was venting its disgust at Webster's innovations, and he acted in accordance with the common opposition to Webster. His work found much favor, though it contained many eccentricities of form. Worcester is still the authority for many American writers, though his dictionary is practically dead.

The Century Dictionary might well have been called "Whitney's Dictionary," for its chief editor was William Dwight Whitney, and he determined the spelling for it. All of its spelling peculiarities are his.

The Standard Dictionary has more peculiarities and oddities than the Century. One editor practically dictated all of them. He was Francis A. March, known as consulting editor. Herein are some of the oddest possible of spellings, so odd that the one-man choice stamps them plainly.

Each dictionary here named contains some spelling preferences peculiar to itself and not preferred in any other; and each one shows the personal choice of some one man. It is impossible for any one to select one of the choosing editors as actually a better authority than any other one. Such selection must remain also a matter of mere personal preference.

Only one method of truly satisfactory agreement is open for printers. It is the selection of one dictionary as the authority to follow when not directed to spell according to some other. And the only way to assure compliance with such rules is to provide copies of the dictionaries for reference. This, of course, is not to apply, except in the case of accidental error in copy, when a customer's order is strictly that copy be followed.

As fair evidence of the strength with which personal convictions are adhered to, even by supposedly broad-minded scholars, we quote the following from the preface to "English Spelling and Spelling Reform," by Thomas R. Lounsbury:

"There is no one subject upon which men, whether presumably or really intelligent, are in a state of more hopeless, helpless ignorance than upon that of the nature and history of English orthography. No serious student of it can read the articles which appear in newspapers, the communications sent to them, or the elaborate essays found in periodicals, without being struck by the more than Egyptian darkness which prevails. In nearly every one of them mistakes of fact not merely exist, but abound. Most of the assertions made lack even that decent degree of probability which belongs to respectable fiction. Even in the very few cases where the facts are correct the inferences drawn from them are utterly erroneous and misleading."

Professor Lounsbury does not stand alone in thus contemning the common understanding of orthography, although his is one of the most virile public expressions of such opinion. We can not ignore the fact, however, that the tremendous weight of almost universal usage is still opposed to innovation, and must be so at least until some more promising method of simplification is devised than any yet proposed.

Steel Chimneys and Their Protection

CHIMNEYS built up of steel plates require protection, both inside and outside, if they are to have reasonably long life, and perform their work properly. The outside of a chimney is exposed to the action of sun, wind,

and rain, and the approved method of protecting it from rust is to give it a coat of good paint, which should be renewed whenever and wherever it shows signs of peeling off and exposing the metal to the influence of the elements. On the inside the chimney is exposed to the action of the gaseous products of combustion, which may have a temperature of several hundred degrees. Any form of paint would, therefore, be quite useless. Besides, it must be remembered that the gases which flow up the chimney are derived from the combustion of fuels containing carbon, hydrogen, and sulfur, and, therefore, contain carbon dioxide, steam and sulphur dioxide. The steam in the chimney gases will condense if cooling takes place to any great extent, and the moisture will combine with the dioxides of carbon and sulfur to form carbonic acid and sulfurous acid. Both of these acids are corrosive in their action on iron, and they are particularly active in the presence of heat. Therefore, the inside of the chimney needs to be well protected.



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Large trees are quickly stripped of their fruit

The usual method of protecting the interior of a steel chimney is to line it with brick, which is laid up against the wall of the chimney. It is advisable to fill the interstices between the lining with a grout made of cement, as this will not only give support to the brickwork, but will at the same time prevent the corrosive acids from reaching the shell. Such a lining should extend to the top of the chimney to be effective. If it is carried up only half-way or even to two-thirds of the full height of the chimney the corrosion is localized at the part of the structure that it is most difficult to reach. The formation of moisture, due to condensation of vapor in the flue gases, will occur in the upper part of the chimney rather than in the lower, because the gases grow colder as they ascend, due to radiation from the shell of the chimney. It is, therefore, very advisable to carry the lining all the way up to the top. It will be

found upon observing steel chimneys that are in service that the signs of discoloration and corrosion on the outside are largely confined to the upper half of the structure. The rings or sections composing the chimney are put together in such a way that each overlaps on the outside of the ring below it, so that the edges of the circumferential seams face downward outside. This construction prevents rain and snow from collecting on the edges of the plates outside. On the inside, however, the edges face upwards, and if moisture is formed it will lodge on these edges, find its way through the joint and run down outside, streaking and discoloring the chimney. A continuous lining from the top to the bottom will lessen the radiation loss, reduce, and, perhaps, eliminate condensation, and in any case eliminate the troubles arising from the moisture from the edge of the plates.

—The Practical Engineer.

Ropiness in Bread

SINCE the Government regulations in regard to the milling of wheat and the addition of other materials to wheat flour came into force, complaints of the inferior quality of the bread have been rife. That bread made with flour of the type now used should be particularly susceptible to ropiness is what might have been anticipated from consideration of the known facts in regard to this disease. The production of ropiness in bread was thoroughly investigated by E. J. Watkins some years ago, and the results of the investigation were communicated to the London Section of the Society (see *Jour. Soc. Chem. Ind.* 1906, 350). In view of the Government regulation that bread must not be exposed for sale until it is at least 12 hours old, it is important to note that the disease usually becomes evident only after from 12 to 48 hours from the time the bread has left the oven. It appears to develop at the center of the loaf and progress gradually outwards. The bread acquires, at first, a faint sickly odor, and brownish spots appear in the crumb and gradually extend, the central portion of the loaf ultimately becoming moist and sticky, so that it can be drawn into long gummy threads. Under specially favorable conditions the disease develops to such a degree that the whole of the crumb is converted into a slimy brownish mass, having a strong valerian-like odor. Bread made from flour containing bran is much more liable to the disease than that made entirely from white flour. Watkins succeeded in isolating the micro-organism responsible for the disease and identified it as *Bacillus mesentericus fuscus* (Flügge), which is frequently found in soil and on vegetables, etc. It was shown conclusively that the bacillus is introduced into the bread by the flour, probably on the bran coating. The bacillus is a prolific spore-former, and the spores are capable of resisting relatively high temperatures for prolonged periods, and hence cannot be destroyed by baking the loaves for a longer time than usual. Increasing the time of baking, however, produces a drier bread, and is advantageous in this respect, since dryness tends to inhibit the development of the spores. Watkins found that development could be prevented completely by adding a small quantity of acetic acid to the dough, but it is doubtful whether such a method would prove acceptable. He also recommended that when the flour was found to be contaminated it should be used under conditions most unfavorable to the development of the bacillus, i.e., the dough being made slightly acid and the bread quickly cooled and kept at a low temperature and as dry as possible during storage.—*Journal of the Society of Chemical Industry.*

Synthetic Nitrogen Compounds*

A Great German War Industry

THE fact that Germany, with practically all her imports cut off, should be able to maintain and augment her resources of the essential ingredients employed in the manufacture of explosives, has always proved something of a mystery to the uninitiated. It is, for instance, a matter of common knowledge that, so far as the manufacture of nitric acid in this country is concerned, we are wholly dependent upon the import of Chilean saltpetre, or nitrate of soda. At the present time sulphuric and nitric acids may almost be looked upon as the very life blood of any warring nation, and that the Central Empires should have solved the problem of the synthetic production of nitrogen compounds to such a degree as to render themselves entirely independent of the imported raw material must redound to the credit of their technical ability and perseverance.

As an illustration of what Germany is doing in this direction, it may be mentioned that her pre-war consumption of nitrogen was in the neighborhood of 200,000 tons per annum; but, neglecting the fact that she must have erected for war purposes a number of special plants of which we have no official knowledge, there is more or less definite information that, during the current year, she will be in a position to turn out these products to double the extent of her consumption prior to the war. Some three years ago the quantity of Chilean nitrate imported annually by Germany amounted to about 750,000 tons, and this was sufficient to provide for rather more than half of her requirements. Another source was the lime nitrogen, of which she obtained about 40,000 tons annually from Norway, while her gasworks and coke oven establishments made up the remainder. At this time the synthetic processes were, more or less, in a state of experiment, and had no very material effect on the total supplies. Today, the more prominent methods available for the recovery of nitrogen in useful form in Germany may be distinguished under the following headings:—

(a) The recovery of the element from the distillation of coal either in gasworks, coke oven establishments, or by the use of the Mond and similar producers. In such cases the nitrogen is obtained in the form of the well-known gasworks residual, ammonia, and, if desired, to a very much smaller extent, as certain forms of cyanogen.

(b) The synthetic production of ammonia. It is of this process that the future possibilities are enormous, and there is little doubt that it is destined to play a leading rôle in chemical industry, not only in Germany but the world over. Ammonia is produced by bringing about the union of hydrogen and nitrogen in the presence of a special catalytic agent.

(c) The fixation of atmospheric nitrogen with the aid of cyanamide, or lime nitrogen, as it is frequently called. This process is, of course, dependent for its success, from a commercial standpoint, upon a cheap supply of the well-known compound calcium carbide.

(d) The fixation of atmospheric nitrogen with the aid of coal gas, or, more strictly, the gas produced in coke ovens. This is another German process, but although there is definite information of an experimental plant which operated with success at Nuremberg, it is not possible to say, under prevailing conditions, whether the process has been developed on any considerable commercial scale.

NITROGEN FROM COAL

The nitrogen recovered from coal or lower grade fuels, either by carbonization or complete gasification, into a producer gas, is almost wholly in the form of ammonia. Ammonia, as a source of nitrogen, is a particularly useful product to Germany, in that it may be directly converted into sulphate of ammonia for use in agriculture, thus taking the place of the interrupted supplies of Chilean nitrate; or, in the form of ammoniacal liquor, it may be purified and concentrated up into liquor ammoniac, a valuable compound in the manufacture of explosives. But, more important still, it may, with the aid of another process brought to practical perfection by the German chemist, be directly oxidized to nitric acid. There is a good deal of evidence to show that Germany must have realized some years ago that if future events turned out as was to be expected, the nitrogen products which she was in a position to derive from the carbonization of her coal would be inadequate to meet her requirements. Accordingly she instituted, through the agency of the famous Badische-Anilin concern, an exhaustive inquiry into the practicability of producing ammonia synthetically, by bringing about

the union of the two elements hydrogen and nitrogen. The success of such a process was largely dependent upon the economical production of the two staple gases. The manufacture or separation of nitrogen from the atmosphere was made possible by an adaptation of the well-known Linde oxygen plant, while the production of hydrogen, having a purity of over 99 per cent, presents a fairly simple problem, the iron-water-gas process, as now extensively utilized in this country, being chiefly employed. (For a description of this and other hydrogen processes see *The Engineer* January 6th, 1917.)

In spite of the fact that ammonia (NH_3) is a compound consisting of two of the most common elemental substances, its manufacture from these elements presents great difficulties in practice. The outstanding obstacle is the extremely small chemical affinity which the two elements possess for one another, even at a considerable temperature; but union may be effected provided temperature can be introduced in conjunction with immense pressure. Herein lies the practical stumbling-block, for the containers must be so constructed as to be capable of resisting intense bursting stresses, while they are operated at a temperature approaching 700 deg. Cent. Professor Haber, however, after exhaustive trials has managed to override this problem, and there is little doubt—although it is difficult to persuade the average technical man to this effect—that his process, now perfected, is one which will have a revolutionary effect on the chemical and auxiliary industries in the course of the next few years.

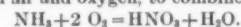
SYNTHETIC AMMONIA

There is no question, particularly in view of the Ostwald oxidizing process discussed later, that ammonia is the most highly desirable form in which to obtain combined nitrogen, in that it lends itself to conversion into a host of essential products. In the Haber process hydrogen and nitrogen, obtained as previously described, are admixed approximately in the proportion of three parts of the former to two parts of the latter. The mixture is then submitted to compression, amounting to some 2,600 pounds per square inch, at a temperature varying from 500 deg. to 700 deg. Cent. Following this treatment, a volume of liquid ammonia, equivalent to about 10 per cent. of the volume of the original gas treated, is obtained. An interesting feature of the process is the fact that no subsidiary apparatus for supplying the necessary heat is required, for the reaction is highly exothermic, and is, accordingly, in itself its own heat producer. In order to effect the combination of the two elements, and to increase the velocity of the reaction, compression takes place in the presence of a special catalyzing material. Haber, if he could obtain it, would employ osmium as his catalyst, but as the entire world's stock of this rare element only amounts to a comparatively few pounds, other substances have had, perforce, to be utilized. Uranium, usually admixed with a liberal proportion of iron or manganese, is generally made use of; and even iron itself will answer the purpose, provided a high degree of efficiency is not looked for. The gaseous ammonia, after passing through the compression chamber is led into a condenser of ordinary construction in which the ammonia is deposited in liquid form and forthwith collected. In some cases, however, a concentrated solution is obtained by admitting water, in the requisite quantities, to the cooling apparatus. The risk from explosion during the process is somewhat considerable, as may be judged from the fact that the chief plant in operation prior to the war at Oppau, was set up within bomb-proof shelters, and was fitted with elaborate tell-tales designed to indicate the approach of danger. Disastrous consequences would inevitably follow the introduction of oxygen or air into the compression chamber, for the merest trace of either would be sufficient to cause violent explosion. It is for this reason that the plants are fitted with special oxygen-indicating alarms. The well-known difficulty of "poisoning" presents itself in this plant as in all processes in which catalyzing materials are employed. For this reason the most careful preparation of the gases is necessary. Sulphur in its various forms is likely to be the chief offender in this direction, and a minute trace of sulphur compounds would be sufficient in a comparatively short time to render the catalyst completely useless. In addition, Professor Crossley states that other active poisons are selenium, tellurium, phosphorus, arsenic, and boron, or the hydrides of these elements; also many organic compounds and certain metals having low melting points, such as lead, bismuth and tin. These last-named, in the presence of hydrogen, would easily be

formed by reduction from their compounds. It is seen then that, in addition to ensuring a gas free from poisons, it is essential to prepare a catalyzing medium which itself contains no substances by which the same effect might be occasioned.

THE OSTWALD PROCESS

Since the production of synthetic ammonia has been placed on a sound footing, both from a practical and commercial standpoint, the most noteworthy development in the direction of producing nitrogen compounds is the Ostwald oxidizing process, whereby ammonia may be transformed into nitric acid. Thus we have an example of one essential form of combined nitrogen being converted into another form, which, in the light of prevailing conditions, is the more valuable of the two. Theoretically, the Ostwald process is a simple one, for it consists in causing ammonia and air, or a mixture of ammonia with air and oxygen, to combine thus:—



Combination is effected, as in the Haber process, in the presence of a catalyst, but, in this case again, the most scrupulous care is essential in view of the possibilities of "poisoning," the catalyst in the Ostwald process being highly susceptible to the effect. This contingency necessitates the use of only the purer forms of ammonia, hence sources of ammonia, such as gasworks and coke ovens, are not altogether suitable, owing to the increased expenditure on purification. As a fact, however, it has recently been shown in America that the use of coke oven ammonia is practicable, providing purification is thorough. Albeit, there is little question that the Germans have discovered that synthetic ammonia lends itself admirably to the process, although cyanamide undoubtedly provides a suitable substance. The Ostwald process has had its critics, particularly in view of the fact that the efficiency of conversion realized is comparatively low amounting, under best conditions, to no more than 85 per cent. An American authority has said that—the exigencies of war apart—the new method is scarcely capable of competing with the ordinary nitrate process for the manufacture of nitric acid, or with that of the electric arc. As an illustration of his statement he quotes figures which show that the cost of producing nitric acid with raw materials at their present value would be approximately 2.73d. per pound by the nitrate process, and 2.75d. per pound by Ostwald's method, the low conversion efficiency of the latter process largely accounting for its high cost of operation. When all is said against it, however, Ostwald's system possesses indisputable merits owing to the continuous nature of production, the little plant required, and the relatively small amount of power necessary, while the exit gases are several times more concentrated than those from any furnace.

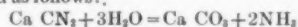
It is pleasing to be able to record that, although up to a recent date, some half dozen European countries had installed apparatus for the manufacture of nitrogen compounds by modern methods, and whereas Great Britain did not at the time figure in the list, there is today a plant at work in this country for producing nitric acid and nitrate of ammonia on the new lines. This plant, according to the chairman of the Nitrogen Products Company, has recently commenced working, although it will be some little time before factory attains its full output. The greater portion of the plant is entirely new in design. It should be recognized that a British concern has secured the rights of the Ostwald process, which is thus, if taken advantage of, as it should be, available for the use of Great Britain and her Allies at a time when nitric acid is a predominant factor in the maintenance of the explosive supply.

NITROGEN FROM CYANAMIDE

The supply of calcium cyanamide is dependent upon calcium carbide, a compound which was, until recent years, manufactured in comparatively small quantities. Where, however, sufficient power is available—and abundant water power is generally regarded as the *sine quâ non*—it is an easy matter to produce the carbide in an electric furnace capable of attaining a temperature of about 3,500 deg. Cent. The process is based upon the fact that if lime is admixed with carbon and heated in a crucible, the resultant products will be calcium carbide and carbon monoxide. On the practical scale lime or chalk is utilized, while the carbon is supplied in the form of anthracite, and although Norway, and particularly the region round Odda, is the home of the carbide industry, the anthracite was, in pre-war days, usually shipped from this country. In fact, owing to the lack of coal-washing facilities over here, the coal was in

**The Engineer*.

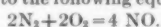
some instances discharged en route at Hamburg to undergo this treatment. As turned out from the electric furnace the raw cyanamide possesses the chemical formula Ca CN_2 , and contains about 25 per cent of nitrogen. In order to convert this product into ammonia it is treated with soda ash and slaked lime, the mixture is then subjected to a temperature of about 160 deg. Cent. in the presence of superheated steam, when ammonia is produced as follows:



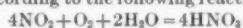
The quantity of lime and soda ash added is comparatively small, amounting in all to only about 5 per cent of the weight of the cyanamide. The reaction itself is highly exothermic, with the result that, once started, it is capable of generating sufficient heat for its own operation. One of the engineers of the American Cyanamide Company has stated that a factory erected in Canada has a capacity for fixing nitrogen equivalent to 90,000 lb. of ammonia per day. A plant destined for erection in America was interfered with by the outbreak of war, and the apparatus, which was to have been delivered by Germany, was commandeered for the purpose of adding to its own units. It is interesting to hear the testimony of the American company to the fact that the ammonia yielded by the cyanamide process is so pure that it may be employed in the Ostwald process without any fear as regards the poisoning of the catalyst. Cyanamide ammonia lends itself to concentration into the anhydrous product, and has been used for this purpose in France to some considerable extent.

NITROGEN FROM COAL GAS

Mention has already been made of the method originating in Germany for fixing nitrogen with the aid of coal gas or coke oven gas. Discovery of this method is due to Professor Häusser, who conducted his research on the lines of the well-known fact that when a combustible product such as coal gas or producer gas is exploded traces of nitric oxide gas (NO) are found. As a result of explosion nitrogen and oxygen combine according to the following equation:



The nitric oxide possesses, however, a tendency towards oxidation into nitric oxide (NO_2), but it has been shown that if extremely rapid cooling is arranged for this oxidation may be checked. The process is carried out in steel explosion chambers of immense strength, connected, in the original plant, to a compressor which delivered the mixture of gas and air to the chamber at the desired pressure, ignition taking place by means of a magneto within the chamber. After explosion has occurred an exhaust valve is released, and the products are scavenged out of the cylinder by a current of compressed air. The method of obtaining a considerable temperature drop is ingenious, and brings in the principle of sudden expansion through an orifice. For instance, immediately following the explosion the exhaust valve opens and permits the products to expand suddenly in the collecting vessel. Professor Häusser originally adopted the idea of spraying a jet of water into the chamber, but this method possesses a drawback in that it gives rise to the formation of nitrous acid (HNO_2), which is found to destroy the valves. In the latest type of plant, so far as is known, gas and air are compressed not in the same but in distinct compressors, and in order to increase the temperature of explosion, and therefore the efficiency of conversion, the air is pre-heated before passing to the chamber. This pre-heating is effected by means of a suitable gas furnace. On leaving the explosion chamber the products are condensed by passage through a coil submerged in water, when the water produced by combustion is thrown down. The remaining products are then led through a cast iron oxidizing tower, and from that they travel through scrubbers, in which the nitric acid is washed out. The acid is produced according to the following reaction:



In this way a product of some 40 per cent strength is yielded, and this may be concentrated by evaporation and re-distillation. As regards the Nuremberg plant it is gathered that the yield of nitric acid amounts to about 7 lb. per 1,000 cubic feet of gas treated, but it is obvious that if gas is to be used in bulk for this purpose the economies of the process will not present a particularly alluring prospect if the value of nitrogen products, owing to the increased output which may be expected from the growing use of synthetic methods, is likely to fall much below the normal figure. The process, however, has distinct advantages when considered in conjunction with those coke ovens where some difficulty may be found in disposing of the surplus gas.

A New Microscopic Test for Paper

In the manufacture of fine papers the use of bleached pulp is necessary in order to produce a sheet of proper appearance and strength. It may often be, however,

that a manufacturer of paper will take a chance on the use of the cheaper unbleached pulp, or even introduce groundwood, trusting that the substitution will go without detection. Within a recent period there has been developed a method of staining paper fibers such as will reveal under the microscope the proportion of bleached to unbleached pulp that has been used in the manufacture of the paper. The color reactions of the stain are remarkably clear and brilliant, all bleached chemical fibers showing up bright red while the unbleached material and the ground wood, jute, or other substances containing lignin take on a distinctive blue tint. The reagent can thus be used as a diagnostic test for the presence in paper of ground wood as well as unbleached chemical pulp. The new stain was described at a recent meeting of the Technical Association of the Pulp and Paper Industry by Charles G. Bright, of the Chemical Laboratory of the Kimberly-Clark Company, Neenah, Wis.

The principle of the method is first to stain the fibers with Cross and Bevan's ferric ferri-cyanide solution, which colors the unbleached sulphite green, on account of the lignin contained in it, and leaves the bleached sulphite colorless. This alone gives a good distinction, but by subsequently staining with a red substantive dyestuff, the green of the unbleached is changed to a very pure blue, the bleached being colored red, thus giving a most striking contrast.

The problem is to adjust the treatment with the two solutions to bring out the sharpest contrast. If the treatment with red is too severe some of the unbleached fibers are likely to be colored purplish, or in extreme cases take on a dull, dirty red color. On the other hand, if the treatment with ferric ferri-cyanide is continued for too long a time or at too high a temperature, the reagent has a tendency to decompose and form a deposit on the slide as well as on the bleached sulphite, so that the latter turns a dull purplish color when subsequently stained with red.

The results depend on three factors—namely: (1), the concentration of the solution; (2), the temperature at which each is applied, and (3), the length of time each is allowed to act. In experimenting with this method these factors were varied separately and the combination which gave the best results was chosen.

The solutions are prepared according to the following procedure:

FERRIC FERRICYANIDE

Sol. A-N/10 FeCl_3 —2.7 grams $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ per 100 Cc.

Sol. B-N/10 $\text{K}_3\text{Fe}(\text{CN})_6$ —3.29 grams per 100 Cc.

After diluting to the mark with distilled water filter through dry filters into clean, glass stoppered bottles—protect from dust. Equal volumes are mixed fresh whenever the reagent is used.

SUBSTANTIVE RED

Benzopurpurin 4B extra (Bayer Co.)..... Gm. 0.4
Oxamine brilliant red BX (Badische Co.)..... Gm. 0.1
Distilled water..... Cc. 100

Have the water hot and stir in the dyes slowly.

The stain is placed in a tall, narrow cylindrical beaker, which is set into a water bath. The slides are suspended in the beaker by a clamp which holds them at their upper ends, the clamps resting across the top of the beaker. The bath is heated by a small bunsen burner with a pilot flame. The burner can be turned on full to heat the bath up to the required temperature (35° and 45° Cent.); then by turning off the burner and regulating the pilot flame the bath can be kept at the required temperature without much difficulty. A thermometer is suspended in the beaker of stain beside the slides. The beaker should be as small as possible so as not to use up too much stain at one time.

MODUS OPERANDI OF STAINING WITH FERRIC FERRICYANIDE

Staining with ferric ferri-cyanide is done as follows:

Mix equal volumes of two fresh solutions and heat to 35° Cent. regulating the waterbath so that it will remain within one degree of the temperature named, for 15 minutes. The dry slide is then dipped in water to moisten it uniformly, so that air bubbles will not be formed when it is immersed in the stain. If air bubbles are formed the fibers under the bubbles will not be stained. If dipping in water still leaves bubbles, they can be removed by blowing across the slide from the edge. The slide is then suspended in the stain and left there for 15 minutes at 35° Cent. It is then removed and washed by dipping in and out of a beaker of distilled water six times and repeating the process in a fresh beaker of water. The slide can then be placed wet into the red solution, but it is perhaps best to dry it out so that the fibers will be stuck on tightly again in case they have been loosened to any extent by the treatment.

APPLYING THE SUBSTANTIVE RED STAIN

Staining with the substantive red solution is done as follows:

A fresh solution is heated to 45° Cent., and the slide, after moistening and excluding bubbles as before, is suspended in the solution for five minutes at 45° Cent. and immediately washed in two beakers of distilled water.

The slide is then dried and a cover glass placed on with a drop of balsam.

DIRECTIONS FOR INSURING BEST RESULTS

To get the clearest, brightest results, distilled water must be used throughout, and the staining solutions must be fresh. The two solutions for ferric ferri-cyanide will keep well if placed in separate bottles. Equal volumes are mixed together immediately before using. The red solution should be made freshly each time for the best results, as it gets thick and stringy on standing, especially when it is being heated up continually.

Staining under the conditions described gives on unbleached sulphite perhaps the deepest blue it is possible to obtain without depositing blue on the slide and on the bleached sulphite; the method also produces the best red on the bleached without turning the unbleached purple. Unbleached sulphite from different mills varies considerably in lignin content, hence some samples stain a deeper blue than others. The foregoing conditions give a satisfactory blue on a sample of high grade imported unbleached pulp as well as a better color on the average run of unbleached pulps, the latter being not so well cooked as a rule. With pulp containing more lignin it is possible to use a slightly stronger treatment with the red and thus get a better color on the bleached without affecting the unbleached.

After a man has had a little experience with the method he can tell by the color of the unbleached whether he may safely continue the staining with the red for six or possibly seven minutes at 45° Cent. At first, however, it is better to follow the directions as given. It is of prime importance to wash out or neutralize every trace of alkali in the fibers, as the blue is decolorized by alkali.

This method of staining will in general give a distinction between pure cellulose fibers and those which contain lignin. Rags, bleached sulphite, soda pulp or any thoroughly bleached material are stained red, while unbleached sulphite, groundwood, jute, or any lignified materials are stained blue. The principal application lies in the estimation of unbleached pulp in book papers. A considerable saving can be made by using unbleached sulphite instead of bleached, hence it is important to know how much unbleached pulp there is in a sheet.

Stellar Motions and Absolute Magnitudes

THE relationship of stellar motions to absolute magnitudes has been further investigated, as regards 1,300 stars of types F, G, K, and M, by W. S. Adams and G. Strömberg (*Astrophysical Journal*, Vol. xlv., p. 293). Parallax determined by the spectroscopic method were available for about 700 of the stars used, and these were supplemented by others derived with the aid of a new formula connecting mean parallax with proper motion. From the parallaxes and apparent magnitudes, the absolute magnitudes are easily calculated, being defined as apparent magnitudes reduced to the distance corresponding to a parallax of 0.1". The stars being divided into groups defined by certain limits of parallax it is first shown that among stars at the same distance from the sun there is an increase of radial velocity with decrease in absolute brightness, and that there is little evidence of any variation in radial velocity depending upon distance from the sun. For the spectral types considered, the increase in velocity is 1.5 km. for a decrease in brightness of one magnitude. It is shown that this effect cannot be ascribed either to distance from the sun, to the law of frequency-distribution of the velocities, or to the effect of stream motion. The same conclusion is reached with regard to the cross linear motions of the stars, and it appears to hold in the mean for apparent as well as for absolute brightness. The stars of types K and M have mean velocities about 1.0 to 1.5 km. higher than the F and G stars of the same absolute magnitude.—*Nature*.

Ink for Skin Localization Marks

THERE is considerable need for an "ink" for the skin for localization marks. It should stain the skin such a color that it will show up against iodine, be unaffected when rubbed with alcohol, ether, acetone, etc., last for some days under a dressing, and not damage or inflame the skin. Captain Finai gives the following formula, which fulfills all these requirements: Acid, pyrogallol, 1 gram; acetone, 10 Cc.; liquor ferri perchlor. fort., 2 Cc.; sp. vini meth., ad. 20 Cc. The mixture keeps well, and can be applied with a brush. The mark is brownish-gray at first, but after a few hours becomes a brilliant black (*Archives of Radiology and Electrotherapy*).

Junkers Engine*

A Novel Internal Combustion Type Developed in Germany

By Philip L. Scott¹

It was my good fortune to spend the past year (1916) in the laboratory of Professor Junkers at Aachen, Germany, studying at first hand the Junkers double-piston engine. Since returning to this country I have met with many divergent views as to the capability of this engine and will, therefore, confine myself to a discussion of personal experiences and of certified reports of tests relating to the performance of the engine.

In the Diesel-engine cylinder potential chemical energy is transformed into kinetic physical energy in a space about one two-hundredth part of that of a steam plant of equal capacity, the boiler alone considered.

The difficulty of controlling this exceedingly violent transformation is only too well attested by the troubles attending early developments and unfortunately still far from being overcome.

PROGRESS OF DEVELOPMENTAL WORK

The problem was first attacked in the year 1892 by Professor Junkers and Mr. Oeschelhauser in connection with the construction of a gas engine, which never was successful because the problem of introducing gas into the cylinder of a double-piston engine had not been solved. During the following sixteen years labor was continued unremittingly on the study of transformation in metal containers of chemical energy in readily combustible hydrocarbons into the potential energy of gas under pressure.

Experiments with the combustion bomb came first in which the influence of piston motion was removed; the effect of eddying, pressure, and temperature on heat transfer to and through the metal wall was also investigated. Then came experiments on a special apparatus having free pistons operating in cylinders that could be completely closed at and after ignition. In this way the influence of gas motion to and from the cylinder was eliminated.

So, one by one, the various problems were solved and valuable information was gained regarding the transfer of heat from a gas to and through a metal surface. The final experiments were made on a compound internal-combustion engine using an explosion pressure of 250 atm. (3675 lb. per sq. in.) in the high-pressure cylinder.

After sixteen years of research, the latter part of which was devoted entirely to the idea of using oil as a fuel, the first double-piston engine was built in 1908. The first engine is still running (a tandem cylinder was added in 1910) and running so well that it is often used for exhibition and demonstration purposes. It is a 150-hp., two-cylinder horizontal tandem engine. The bore is 200 mm. (7.875 in.); stroke, 800 mm. (31.50 in.); revolutions per minute, 220; normal mean effective pressure 10 atm. (147 lb. per sq. in.); overload mean effective pressure 15 atm. (220 lb. per sq. in.).

METHOD OF OPERATING DOUBLE-PISTON ENGINE

The two-stroke constant-pressure cycle is used, giving a power impulse every revolution and requiring a combustion pressure but little higher than the compression pressure. This cycle as used by all Diesel engines must be carefully distinguished from the one on which most gasoline engines operate; the latter has a combustion or explosion pressure much higher than the compression pressure. The constant pressure cycle requires a combustion of the fuel such that the pressure neither rises nor falls during the period that follows immediately after the compression period. As a result the ratio of mean effective pressure to combustion pressure can be high.

The Junkers engine has two pistons operating in the same cylinder and moving in opposite directions. The inner piston is connected to the center crank of a three-throw crankshaft; the outer piston is connected through a yoke and side-rods to the outer cranks of this same shaft section. In some designs, in which the power can be taken advantageously from two shafts, the side-rods are dispensed with and a crankshaft is

placed at each end of the cylinder, each piston being directly connected to the nearest shaft. This construction lends itself admirably to submarine work. The pistons are kept in proper relation by gearing or connecting-rods lying alongside the first cylinder of the engine. The preponderating advantage of this mechanical arrangement is the perfect balance of mass attainable.

The constant-pressure cycle is applied to this mechanism as follows: In Fig. 2, A the pistons are approaching each other, compressing air alone, line FA in the ideal card. Just before the point A, when the pressure is about 48 atm. (705 lb. per sq. in.) and the temperature of the air about 1200 deg. cent. (2192 deg. fahr.),

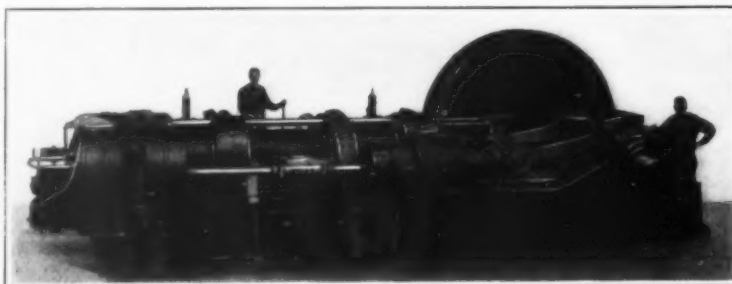


Fig. 1—An experimental Junkers engine of 1,000 H. P.; two-cylinder, double-piston, tandem, direct reversible

the fuel injection begins and the pressure rises to about 50 atm. (735 lb. per sq. in.). Injection continues, the pressure remaining constant, along line AB. At point B the fuel injection is stopped and expansion of the gases commences along line BC. At point C the pistons have reached the position shown in Fig. 2, C. At this point the outer piston opens a row of ports and the gases exhaust to almost atmospheric pressure; line CD in the card. At point D the pistons are in the position shown in Fig. 2, D, and the inner piston is uncovering a second row of ports through which the scavenging air enters. Scavenging takes place along lines DE and EF in the card, the pistons being in the position indicated in Fig. 2 E. Cold clean air under a pressure of 1.5 to 2

lb. per sq. in. rises through the cylinder, forcing the exhaust gases out ahead of it. A charge of pure air is left in the cylinder when the ports are again closed and compression begins as indicated in Fig. 2 F. This completes the cycle. It will be noted that this is the best method of scavenging possible. How closely the Junkers engine approximates this cycle is shown by the photograph of an actual indicator card, Fig. 3.

PRESENT STATUS OF ENGINE

The engine met with severe trials when first placed on a commercial basis, a notable example being the vertical tandem 800-hp. engine on the ship "Primus." Mistakes are often most useful occurrences and the difficulties met have greatly accelerated the development of the present designs, which have perfect records to show.

There are now many prominent foreign licensees, among whom are Nobel & Sons, Russia; Actien Gesellschaft Weser, Germany; Doxford & Sons, England; Du Jardin, Belgium; and the Allgemeine Electricitäts Gesellschaft (A. E. G.), Germany.

The engine was never built commercially by Professor Junkers himself until just at the outbreak of the war.

Since 1914 amazing strides have been made in Germany. The output of the A. E. G. has been so large as to cause this company and the Hamburg-American Line to combine in building Junkers-engine vessels of medium and large tonnage. An island in the Elbe has been purchased for the yards and factory. The A. E. G. at first built high-speed types, but is now taking up the large marine engine just mentioned and also submarine, auto-truck and airplane engines.

In addition some 700-hp. engines, 400-mm. bore (15.7 in.) by 800-mm. stroke (31.5 in.) of the two-cylinder horizontal tandem type have been built by Erhardt & Sehmer. One of these is now in operation in a mine. There are 450-hp. horizontal tandem engines running at 90 r.p.m. for shallow-draft boats in the Donau River. Doxford & Sons have built a 500-hp. vertical single-cylinder engine. The locomotive problem has been carefully studied and several projects made, but no machine has as yet been constructed.

Of the machines that I have seen myself or whose operators I have known, there are two 400-kw. direct-coupled dynamo units on one of the German cruisers now in active service; a 250-hp. engine that served continuously for a year for factory power; a similar machine that has operated a government tugboat for a year and is to the best of my knowledge still in operation; a 100-hp. engine on a small yacht; a 1000-hp. stationary machine and a 150-hp. stationary machine. As stated, these are the engines of which I have personal knowledge and are but a few of the whole number in operation.

I saw but was not allowed to examine carefully an airplane engine of 200 hp. It is probable that a similar one of 400 hp. is now on a military Junkers airplane. Also an auto-truck engine was reported to have been successful on the test stand of the A. E. G. and a 140-hp. farm-tractor engine was ordered by a Russian firm just before the outbreak of the war.

AIRPLANE, TRUCK AND TRACTOR ENGINES

The airplane engine was a 200-hp. machine running at 1000 r.p.m. There were four cylinders lying horizontally with a crankshaft at each end and no side connecting-rods. The crankshafts were held in proper relation by gearing at one end and the propeller was driven by an intermediate gear in this train. In the new airplane engine, which should now be in service, direct injection of fuel is used. No great difficulty with scavenging at high speed has been encountered. In the Aachen Laboratory successful experiments with direct injection were carried out on an 80-hp. engine running at 800 r.p.m.

The auto-truck engine was reported as successful on the test stands of the A. E. G., but no details were available.

DETAILS OF MARINE AND STATIONARY TYPES

Most of my time was spent on a marine engine of 250 hp. and a stationary type of 1000 hp., Fig. 1.

The marine engine was of the three-cylinder direct-reversible type, giving 250 hp. at 250 r.p.m.; the bore

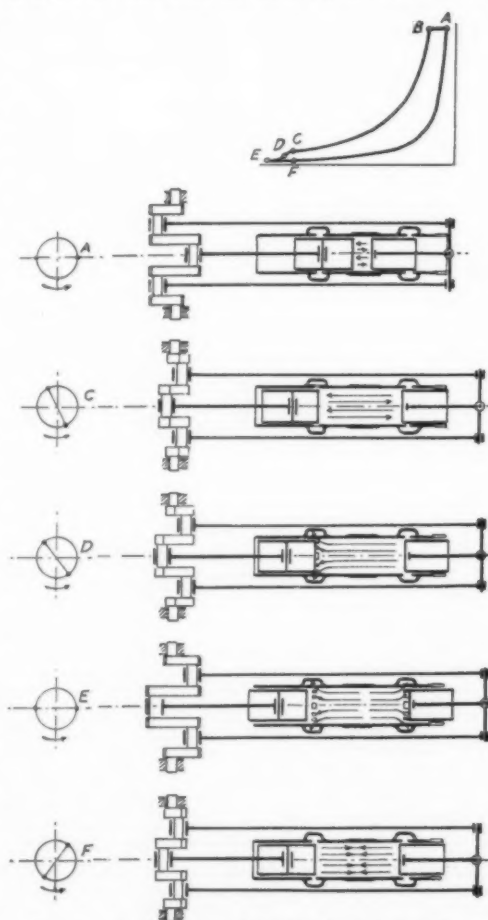


Fig. 2—Cycle of the Junkers double-piston engine

*From a paper read before the Society of Automotive Engineers and published in the Journal of the Society.

¹Engineer, De La Vergne Machine Company.

was 200 mm. (7.875 in.), and the stroke 700 mm. (27.5 in.); the normal mean effective pressure was 10 atm. (147 lb. per sq. in.), and the overload 15 atm. (220 lb. per sq. in.); the pistons were cooled, but without external connection. It had a three-stage air-compressor. This machine was connected to a Junkers hydraulic dynamometer for test purposes.

Two types were developed from this machine. A 400-hp. tugboat engine designed to run at 100 r. p. m., built without crossheads in order to reduce the height, and an engine of the same stroke and bore with crossheads developing 400 hp. at 100 r. p. m., but designed to develop 740 hp. with maximum mean effective pressure and a speed increase of 15 per cent.

The original engine from which these engines were developed had a speed range of from 30 to 300 r. p. m., and a mechanical efficiency of 73.5 per cent. (including power for pumps and air compressor). It had run for a year in factory service and had been sent to Aachen for experimental purposes in connection with the use of tar oil as a fuel.

Tar oil is little known in America as a Diesel engine fuel, but it is the most difficult fuel to burn properly, though hardly more viscous than water and containing no asphalt. The burning of oils having a high asphalt content is not very difficult, although combustion must be perfect in order to avoid the heavy pitch-like substance that slowly collects on the pistons and prevents lubrication.

Tar oil is a mixture of the three fractions next to the last, pitch, in the distillation of coal tar. It is dark brown in color, a little heavier than water (specific gravity 1.040 to 1.150) and contains a hydrocarbon similar to carboic acid in structure, which gives the oil a corrosive action on metal and makes a strong irritant on the skin. Its use in Germany was becoming a necessity, owing to the scarcity of crude oil distillates.

Perhaps because its hydrocarbons belong to the benzol ring and not to the benzene chain, this oil is excessively tenacious of its chemical energy, and as compared with crude oil distillates, requires an immense amount of heat to start oxidation. A greater initial temperature is necessary for tar oil to start combustion, but, because of its tendency to burn explosively once the reaction has started, this is an undesirable feature the moment combustion begins. It was not an easy problem, but it was solved eventually and the engine can be started cold (16 deg. cent., or 61 deg. fahr.) with tar oil. It is the only engine that has accomplished this. The double piston lent itself admirably to the solution of this difficulty.

CONDITIONS DURING INJECTION OF FUEL

Because of the very high compression (about 700 lb. per sq. in.) in the Junkers engine the temperature in the combustion space is much higher and the pistons become and are allowed to remain considerably warmer than is the usual practice. The oil is sprayed into the cylinder in two fans, one directly across the face of each piston when they are at the inner dead center. The high heat capacity of the iron promotes warming of the oil far more readily than air, aiding the initial combustion. But as soon as the pistons recede they draw with them the thin layer of burnt gases formed by the initial combustion and lying between the piston head and the oil spray. The hot metal then exerts no influence on the oil, and two oil layers inclose the hot compressed air and retard the explosive effect.

Since injection of fuel takes place during from 30 to 40 deg. of the crank circle, the oil spray is relieved of this too intense heating necessary to initial combustion during the greater part of the injection period. In a single-piston engine this would be impossible, since, if the fuel valve is vertical, the oil strikes the piston continuously during the injection; if the valve is horizontal, the fuel spray always remains in close proximity to the cylinder head.

VALVE GEAR TO ATTAIN WIDE SPEED RANGE

The marine engine is direct-reversible and has a speed range of from 30 to 300 r. p. m. A special valve gear makes possible this wide range by changing the angle of advance, the period of injection and the lift of the fuel-valve needle with each variation in speed or load. These changes are necessary to permit slow speed and high-speed operation and to obtain fuel economy at light load.

With fixed cam action the speed of injection of the fuel (time element of injection) remains constant regardless of the engine speed, since it is dependent solely on the injection-air pressure. Also the speed of combustion remains constant. Hence, when the engine runs slowly and the angle of advance, period of injection and valve lift all remain the same as for high speed, the fuel will be shot into the cylinder and will

have time to burn, perhaps even before the pistons have passed their inner dead center. Of course, then, there is no longer a constant pressure combustion, which is the basis of Diesel engine design. Either the safety valves blow or the bearings or crankshaft are damaged and sometimes broken. More often the fuel-valve needle is forced open and the valve seat and pulverizing element injured.

If the engine runs still more slowly, the oil is injected and begins to burn, but the fuel valve remains open for the same part of the stroke, and excess compressed air blows through the valve. As stated, the time element of injection remains practically constant, but when the engine runs slowly, the cam action is also slower and the valve remains open for a much longer period. This rush of compressed air actually blows out the fire in the cylinder and the engine stops.

The reverse is true at high speed. The fuel valve is not open for a time period long enough for the complete injection of the fuel, and the engine under load cannot have its speed increased, or else the output falls off. In addition to these elements tending to result in



Fig. 3—Reproduction of an actual indicator card

danger and stalling, the fuel consumption is enormously increased, because what appears as but slight changes from correct injection conditions will greatly affect the combustion. So much energy is handled in so small a space when a cubic centimeter of oil is injected, that it must be done with great exactness to secure the intended results.

For these reasons Professor Junkers has developed this variable injection control combined with the fuel control. The angle of advance can be regulated for each cylinder alone if desired. Further, the injection air pressure can always be immediately controlled from the operator's stand.

The two levers that controlled this engine were so arranged that the fuel and air for starting could be either operated independently, effecting a great saving in air and allowing much greater speed of reversing in the hands of a skilled operator; or interlocked, avoiding dangerous conditions when operated by an unskilled man. Reversing could be accomplished in from five to six seconds. This engine was started 96 times on an air supply of 19.5 cu. ft. originally at 85 atm. (1210 lb. per sq. in.) pressure.

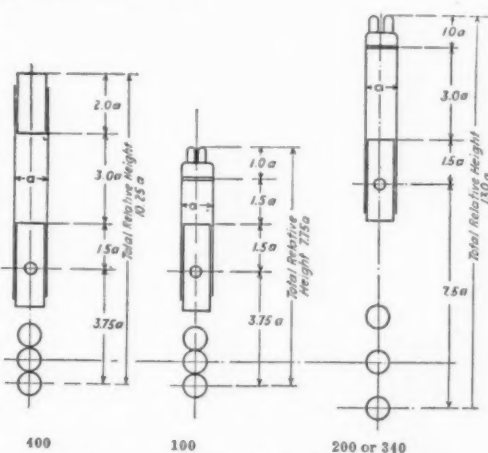


Fig. 4—Relative engine heights and outputs

The pistons are not water-cooled. They have, however, a special self-contained cooling device, which prevents the temperature of the piston head from becoming excessive. A piston or cylinder was never cracked in my year's experience with this engine.

DETAILS OF 1000-HP. STATIONARY ENGINE

The stationary engine, Fig. 1, was of the two-cylinder horizontal tandem direct-reversible type, giving 1000 hp. at 180 r. p. m. It ran successfully, however, at speeds from 25 to 220 r. p. m. The pistons were water-cooled. The cylinders were 450 mm. bore (17.8 in.), and 900-mm. stroke (35.6 in.). The normal mean effective pressure was 10 atm. (147 lb. per sq. in.), and the overload, 14 atm. (207 lb. per sq. in.). The air compressor was of the four-stage type. This engine was direct-connected to a Junkers hydraulic dynamometer for test purposes.

The engine was built especially for experiments in the development of high-power marine engines for war vessels, in which it is desirable to have all machinery below the water line.

In the five years that this engine has been running, trouble due to unequal wear has not appeared, and the cylinders have not been changed. In spite of the fact that this engine has an excessively heavy bedplate, that the flywheel is twice as heavy as is necessary for marine work, and also that it is a slow speed machine (180 r. p. m.), the weight is but 64 kg. (141 lb.) per b. hp. with the flywheel included.

MANEUVERING THE LARGE ENGINE

The large engine was started by air at a pressure of about 40 atm. (590 lb. per sq. in.). Because it had only two cylinders, barring over was necessary until an air starting-valve was brought into action. Then the main air tank was opened, and the starting lever drawn back, bringing the cams into operation. When the engine had attained 100 to 120 r. p. m. (in about 4 sec.) the fuel was turned on by a handwheel at the operator's right and the starting lever allowed to return. Ignition followed immediately and the engine was up to speed in about 3 sec. The injection air was turned on before starting and was regulated, when necessary, by a valve at the side of the fuel control. The air compressor was also regulated from the same point.

Reversing was accomplished by first cutting off the fuel, then throwing over a lever reversing the cam action and pulling back the starting air lever. This admitted air to the cylinders on the compression stroke and stopped the engine in one or two revolutions. The safety valve relieved excessive pressure. The starting lever was merely held back until the engine began to turn over in the reverse direction, when it was released and the fuel turned on again. The time required was about 15 seconds.

Its fuel consumption at normal load is 176 gm. per b. hp. per hr., referred to oil of 10,000 cal. per kg. This is equivalent to 0.387 lb. per b. hp. per hr., referred to oil of 18,000 B. t. u. per lb., or 0.366 lb. per b. hp. per hr., referred to oil of 19,000 B. t. u. per lb. The engine had scavenging pumps and an air compressor 50 per cent. larger than necessary to take care of overload.

ADVANTAGES OF DOUBLE-PISTON CONSTRUCTION

Perfect balance of moving parts is possible with the double-piston engine. This is of immense value in airplane and high-speed automobile engines.

The double-piston engine works best on the heavier (cheaper) fuels. For the airplane and automobile the compression is somewhat reduced so that kerosene is an ideal fuel. In view of the present cost of gasoline this point requires no emphasis.

It is a two-stroke cycle engine with the full double output of a four-stroke cycle engine, but with 1.5 to 1.7 times the output for the same piston displacement. Further the Junkers engine has a mean effective pressure of 150 lb. per sq. in. Three times the output of a four-stroke cycle engine of the same displacement can be expected.

The fuel consumption is the lowest possible, which means greater range for the same amount of fuel than is possible with the present types of engines. This is of great importance in aviation.

This engine has but one valve for each cylinder and no electric or other ignition system, the heat of the compressed air being more than sufficient. An overload of 50 per cent is possible.

OBJECTIONS TO DOUBLE PISTON

The double-piston engine is criticized because of the so-called multiplicity of parts. At first the mechanism connecting the upper piston to the crankshaft was made rigid, and the side rods expanded unequally, throwing the pistons out of line. This connection is now flexible and never during my observation did it give any trouble or require any attention.

The assembly of these parts can be of the least careful kind and still no trouble will appear as the members are the simplest form of linkage, joints being all of the pin type (without bushings). The yoke is permitted to rock in the piston. There are three pin joints between the yoke-end and the crankshaft. The side rods are free to expand or contract. They can be set one or two inches out of line and will still operate freely.

Although quite an unskilled workman at that time, I was given the job of taking out and replacing pistons so that I know this mechanism quite well. The time required for removing both pistons in the 250-hp. marine engine was about 15 min. There is in reality only an extremely slight motion in these joints. It is a question either of an extra piston and the large, rugged

and fool-proof connection necessary or of a cylinder head and the multiplicity of comparatively delicate valves and valve-operating gear.

In the four-stroke cycle engine the cylinder head is not so troublesome as formerly, but in the two-stroke cycle engine it is not so far advanced as to be called entirely reliable. The valve question need not be enlarged upon, for it is evident that the parts are far greater in number and that the assembly requires the highest degree of accuracy.

OUTPUT FOR DIFFERENT CYCLES

Two-stroke cycle single-piston engines are built with only one valve, the fuel valve, but no one can show good scavenging, the output being only from 1.5 to 1.7 times that of a four-stroke cycle engine of the same piston displacement per unit of time. The double-piston engine on the other hand gives four times the power of a four-stroke cycle engine of the same bore, stroke and speed.

Given a certain cylinder bore, crank-throw and speed, the outputs of four-stroke cycle, two-stroke cycle and two-stroke cycle double piston engines are 1, 1.5 and 4. The double-piston engine attains the same or a higher mean effective pressure and a better fuel consumption than one of the four-stroke cycle type. Its piston displacement for the same crank-throw is double that of a four-stroke cycle, because the two pistons each have the same crank-throw, and its power impulses come twice as often. Hence the output is four times as great.

COMPARISON OF HEIGHT AND OUTPUT

It may be said that the double piston engine is much higher than the single-piston engine. Assume roughly as design proportions: Bore of both engines, a ; stroke, $1.5a$; connecting-rod to crank, 1 to 5; wristpin to piston head, $1.5a$; height of cylinder head, a .

From Fig. 4 it will be seen that the single-piston engine is 25 per cent. shorter than the double-piston engine for the same bore and crankshaft, but with only one-fourth the output. But they can be compared better if the same piston displacement per unit of time is taken (same bore, stroke and revolutions per minute). Assuming the same design proportions as before, the double-piston engine is seen to be 21 per cent. shorter than the single-piston engine for twice the output if the single-piston engine operates on the four-stroke cycle and for about 20 per cent. greater output if the single-piston engine operates on the two-stroke cycle.

To draw a practical conclusion from this, consider engines of the same height and compare the outputs. Assume a stroke to bore ratio in a Diesel engine of 1 to 1.5 and a piston speed of 5 m. (16.4 ft.) per sec., and a mean effective pressure of 5 atm. (74 lbs. per sq. in.). A Junkers engine of the same height can have a stroke to bore ratio of 1 to 2 and has therefore a higher relative piston speed with the same revolutions per minute, since the stroke is divided between two pistons. The piston speed is actually 3.5 m. (11.5 ft.) per sec. and relatively 7 m. per second.

Also assume the same mean effective pressure for both engines, although that of the Junkers engine is higher in practice. Then the output of the two-stroke cycle Diesel is

$$hp_c = \frac{\pi d^2 \times 5 \times 5}{4 \times 2 \times 75} = 0.167 \frac{\pi d^2}{4}$$

and the output of the Junkers is

$$hp_c = \frac{\pi d^2 \times 2 \times 3.5 \times 5}{4 \times 2 \times 75} = 0.243 \frac{\pi d^2}{4}$$

or 1.4 times the output of the two-stroke cycle engine and 2.8 times the output of the four-stroke cycle engine, assuming the same mean effective pressures.

This fact of lower height for the same output or greater output for the same height is of great importance at present with regard to the submarine.

THREE-THROW CRANKSHAFT

The three-throw crankshaft is often criticized because of its length. Let us think a moment before dismissing the three-throw shaft as inferior to the single-throw shaft. The main bearings are relieved of load in the three-throw shaft. The bending moment (the determining factor in shaft design) is but three-fourths that of a single-throw shaft.

In general the three-throw shaft is about 1.15 to 1.25 times as long and about one-half as heavy as a single-throw shaft for the same output on a two-stroke cycle engine and for half the output on a four-stroke cycle engine. The matter of weight is of importance on account of the present high cost of shafts. The flexibility of this shaft and the fact that the main bearings are relieved of load is exceedingly important since a greater portion of crankshaft breakages are due to the

main bearings being out of line. In the Junkers engine the main bearings have a spherical support.

DISTRIBUTION OF WORK

It is generally desirable to use the two-stroke cycle if the difficulties of loss of work in scavenging and troubles in constructing cylinder head and scavenging pumps can be avoided. The single-piston two-stroke, cycle engine however is almost as large volumetrically as the four-stroke cycle unit of the same output. Its output is 1.5 to 1.7 that of the four-stroke cycle of same piston displacement per time unit, owing to the lower thermal efficiency and loss of work in the scavenging pumps.

The saving in scavenging work is due to the excellent conditions in the double-piston engine, requiring low pressure and securing a charge of clean cool air in the cylinder with only 1.1 times the cylinder volume of scavenging air. A charge of clean cold air is essential. An increase of 75 deg. cent. (135 deg. Fahr.) in the temperature of the scavenging air means a loss in output of 25 per cent.

The overall mechanical efficiency of the engine, as taken from reports of tests made in Aachen last year, is from 72.5 to 73.5 per cent.

AUTHOR'S CONCLUSION

I believe the double-piston engine to be mechanically and thermo-dynamically the best construction. The idea of reducing the heat outflow during the initial part of the cycle has proved itself invaluable. The advantage of mechanical balance and perfect scavenging (better than in the four-stroke cycle engine) is not easily to be measured. The high mean effective pressure, low fuel consumption, and the high output per unit piston displacement are obtained partly through perfect scavenging.

Linguistic and Political Boundaries in Europe

NATIONALITY is to serve as an important factor in determining the boundaries of the New Europe. On broad lines the safest guide to the nationality of any populace is the language commonly spoken, usually the mother-tongue. Consider for a moment the political boundaries, both international and national, of Austria-Hungary. Practically nowhere do they coincide with a linguistic boundary. The only people wholly within that empire are the Magyars, who inhabit a compact block of territory bounded on the south by the Drave and the Maros, on the north by the foothills of the Carpathians, on the west by a line slightly west of south from Pressburg to the Drave, and on the east by a line northeast from Arad. Southeast of the Magyars lie the Rumanians, who extend beyond the Carpathian political boundary; they include islands of Magyar and German settlers, former frontier guards. Along the south and to the southwest the great group of the Yugo-Slavs (Serbs, Croats and Slovenes) extends beyond the confines of Austria-Hungary. To the west lie the Austrian-Germans who fill the Danube valley westwards beyond the frontier. Northwest are the Slovaks, who link with the Moravians and Czechs as one great branch of the northern Slavs. These peoples do not reach the Austro-German frontier, since they meet the Germans within the borders of Bohemia, or the Austro-Russian frontier, since they meet the Poles. To the northeast the Magyars adjoin the Ruthenes, or Little Russians, whose limit is far to the east beyond the Don.

Suppose an independent Magyar kingdom be established, what are the chances of stability? First, a homogeneous race; secondly, a zone railway system which concentrates on the capital, Budapest; and, thirdly, a unity of soil, climate, and products mainly agricultural—all these tend to preservation. On the other hand, there would be no Magyar outlet to the sea, the two great waterways, Danube and Theiss, would not join in Magyar territory, and no boat could journey by Pressburg to Szabadka through Magyar territorial waters for the complete voyage. The great trunk railway from Vienna to Constantinople would only serve the southwestern corner. Finally, would the Magyar kingdom march with Russia on the northeast and with Germany on the west?

Contrast this kingdom with Poland, cut across by pre-war international boundaries. The Poles form the most numerous non-German people in the German Empire; they extend into Austrian Silesia, and practically fill Galicia west of the San. Unlike the Magyars, the Poles reach the sea, along a few miles of coast west of Danzig. They march, however, with Germans on the west, with Russians on the east, and with a Slav people—Czechoslovaks—on the southwest. The linguistic boundaries of Magyars and of Poles rarely lie along rivers or mountain ranges; will the new era bring into play new factors which will determine the stability and utility of political boundaries?—*Nature*.

Correspondence

[The editors are not responsible for statements made in the correspondence column. Anonymous communications cannot be considered, but the names of correspondents will be withheld when so desired.]

The Speculative Value of the Corpuscular Theory

To the Editor SCIENTIFIC AMERICAN SUPPLEMENT:

I wish to answer briefly the letter entitled "The Speculative Value of the Corpuscular Theory," appearing in the Correspondence Columns of the October 13th issue of the SUPPLEMENT. Under this heading, Mr. Devide criticizes the article entitled "The Nature of Matter," which appeared in the SUPPLEMENT of August 11th and 18th.

While Mr. Devide has misunderstood the argument set forth in that article, he is correct in understanding the conclusion to be that matter is no entity at all, but that it is only a form of energy.

Now Mr. Devide, it seems, doubts that proposition and, furthermore, he thinks that, even though it be true, the difference is wholly one of nomenclature, and of no value to philosophy. Since the value or significance of an idea depends a great deal more upon one's training and temperament than it does upon logic, argument would be of little avail in convincing one of the philosophical value of the electron theory. Therefore I doubt that it would be of much use to argue the matter. But I can indicate briefly the way in which the idea has helped us, in order to make it clear why we appreciate it so highly.

Personally, I have found that the thought of a universe of active energy, instead of dead atoms, has been of very real value to us in building up our "View of the World." We have always had difficulty in feeling on very intimate terms with a theoretical world made up of presumably hard and perfectly elastic little blocks or balls, called atoms or molecules. The blades of grass that pushed up so fresh and green in the spring, and the beautiful figures that came on the window pane, of winter nights, these seemed too "human" to be made of such dead stuff as those atoms were supposed to be. The idea of a strange God who was somewhere and who somehow sent mysterious forces that in some unaccountable way made the molecules and atoms wave in just such and such a manner and no other—that seemed a rather artificial and child-like sort of a world. What John wrote about the "Word" which was in the beginning hinted at a deeper and more subtle bond between the blade of grass and the Deity; and Paul's message, that in Him we live and move and have our being, confirmed the feeling, innate, I believe, in almost every human breast, of kinship with the world around us and with the Supreme Being.

To find, then, that scientists had actually shown that the uncongenial atoms were not dead, but were very lively little organizations of energy—that seemed to be the key. Energy was an intelligible term, there was first-hand, inside information on that idea, because one could feel in his own soul the pull and throb of energy. Here was a world with which we could really feel ourselves kin where the grass that grew and the crystal that formed were but other manifestations of the same universal energy that we could feel in ourselves, and where God was an immanent, guiding influence, and not an outside-propelling force. That's the kind of a world we had wanted, and since the corpuscular theory had, as it were, made us feel at home in the universe, we felt very grateful and valued it quite highly. We appreciated then, more fully than before, the sentiment of the Erdgeist in Goethe's Faust: "In the tides of life, in the storm of deeds, I hurl myself hither and thither and to and fro, an eternal ocean, a restless striving, a glowing life. Thus at the roaring loom of time I weave the Godhead's living robe."

Perhaps this "confession of faith" seems altogether too loose and illogical to one who has delved deeply into philosophical literature. But most of us, I feel, get our beliefs first, and our justifications for them afterwards. Because the corpuscular theory has seemed to us to make more intelligible and reasonable our faith in an Immanent Deity, it has had a philosophical value to us.

I have sacrificed dialectic formality and written so frankly because I feel that there may be others to whom the idea of a universe of energy does give a stronger faith, but who may have had the faith shaken by Mr. Devide's letter. Let us remember that the corpuscular theory itself, namely, that matter is composed wholly of energy, is quite well established, scientifically; and let each one find in that idea what value he can, philosophically.

J. C. WHITEHORN.

Modern Analytical Chemistry—I.*

Some Lines Along Which Its Scientific Development Has Proceeded

By A. Chaston Chapman

ANALYTICAL chemistry has often been referred to as the handmaiden of the other branches of our science, and whilst this was an entirely unobjectionable description in so far as it implied indispensable assistance, it was a little unfortunate in that it carried with it a certain suggestion of inferiority. From the dawn of scientific chemistry in the seventeenth century to a period within the recollection of a good many chemists who are still happily among us, analytical chemistry was almost synonymous with chemistry itself, and it is only in comparatively recent times that it has become a separate branch of applied chemistry with its own literature, its own aims, and its own specialized practitioners. While the division of chemistry into various separated branches became inevitable with the enormous development of the science, and had its obvious conveniences, the progressive subdivision of work has not been without its drawbacks, and even its dangers. That it has conducted to a narrowness of outlook and to a mental onesidedness is undeniable, and it is becoming increasingly difficult always to maintain a just sense of proportion to view facts in their true perspective and to keep a firm hold on fundamental principles. Of all the various members of the body chemical, perhaps none suffered more at first by this process of subdivision than analytical chemistry. During the first half of the last century, chemical analysis occupied a very high position, since not only was it clearly the foundation-stone on which the whole chemical fabric was built, but almost every chemist of distinction practiced it assiduously and devoted much of his time to a study of its problems. One need only recall in this connection such names as those of Berzelius, Gay-Lussac, Marignac, Bunsen, Dumas, Stas, Liebig and Wöhler. With the birth of modern organic chemistry and its colossal development during the past half century—a development which, be it remembered, was largely dependent in the beginning on the analytical labors of Gay-Lussac, Liebig, Dumas and other early workers in the field—the analytical branch of our science was gradually relegated to a comparatively humble position. In the presence of this new and fertile field, in which every thrust of the spade served to bring to light some discovery of the highest importance and of the most absorbing interest, it is scarcely to be wondered at that the great majority of chemists should have forsaken the older branch, and that the all-important foundation-stone should have tended to become regarded more and more as merely the useful handmaiden. That the lamp of analytical chemistry was kept well alight during the period in question, notwithstanding the superior attractions of organic chemistry, is evidenced by the epoch-making researches of Bunsen and Kirchhoff on the spectrum analysis, by numerous records of observations on the qualitative electrolytic decomposition of metallic salts, on which the important branch of electrochemical analysis was later on to be founded, chiefly by the labors of Classen and his students, and by the many investigations having for their object the perfection and simplification of methods of gas analysis. Last, but not least, I may mention in this connection the establishment of the Fresenius Laboratory in Wiesbaden in 1848, and a few years later (1862) the foundation of the *Zeitschrift für Analytische Chemie*, the first journal, I believe, which was devoted exclusively to the interests of analytical chemistry. Our own journal, *The Analyst*, did not appear until 1877.

Great as is the temptation, it is not my intention to deal at any length with the history of analytical chemistry during the latter half of the nineteenth century. I will merely content myself with remarking that at a certain point in that history the rate of progress in its scientific development had slowed down so considerably that any chemist taking a superficial survey might well have been justified in supposing that future advances would be restricted to improvements in existing methods and to the extended application of those methods to the solution of new technical and industrial problems. That new lines of progress would be opened up must have seemed highly

improbable, and it is recorded that a certain distinguished German chemist went so far as to utter the dictum that analytical chemistry presented no further problems. My task this evening will be to indicate briefly a few of the main lines along which the scientific development of modern analytical chemistry has proceeded, and to deal—however inadequately—with what I conceive to be the main causes of its restoration to something of its old position as a living and progressive part of our science. Foremost among these causes has unquestionably been the almost unparalleled growth during comparatively recent years of that younger member of the chemical family—I mean physical chemistry. That a proper understanding of analytical chemistry, as of every other department of the science, is dependent on a knowledge of those fundamental laws which it is the special province of physical chemistry to elucidate will appear to most chemists of to-day a self-evident proposition. Yet it was not until the publication of Ostwald's "*Wissenschaftlichen Grundlagen der Analytischen Chemie*" in 1894 that this all-important truth was presented to the chemical world, and not until some years later that it received anything like general recognition—at least in this country. To many generations of students chemical analysis has been taught as a useful art, consisting largely of a series of recipes which if followed conscientiously would usually lead to the desired result. Those recipes had often the authority of great names behind them, and so far as they went they were admirable; but how many of those students were taught anything of the underlying principles, or were put by their teachers in a position to make for themselves such modification of the orthodox processes as might at times become necessary? The result was to manufacture a body of more or less mechanical hand-workers, and if, as fortunately happened, a number of these showed initiative and developed originality, it was in spite of, rather than in virtue of, the instruction they had received. This state of affairs was, however, inevitable, since, as Ostwald has pointed out, it was only with the advent of the general theory of chemical reactions and states of equilibrium that it became possible to elaborate a theory of analytical reactions and to place analytical chemistry on a really scientific foundation. It was then the beneficent work of physical chemistry to infuse new life into analytical chemistry, to help to place it on a firm and wide basis, and to do much to remove the reproach that this branch of chemical science, whilst representing a useful field of highly skilled manual labor, could scarcely be regarded as an intellectual occupation.

In three main directions this revivifying influence has made itself felt during the past twenty years. In the first place, it has supplied the explanation of a vast number of facts which had been arrived at empirically, and are of the greatest importance to the analyst; in the second place, it has greatly stimulated and directed original research, and, finally, it has enriched analytical chemistry with a number of new appliances and has resulted in the introduction of many new methods of inquiry.

Of all the theories of modern physical chemistry, none has had so far-reaching and important an effect on the development of analytical chemistry as those connected with the nature of solution. It is not, in fact, going too far to say that the general adoption of these theories and their application to analytical processes was the means of placing analytical chemistry for the first time on a really scientific basis. The years 1885, 1886 and 1887, which for chemists will ever be memorable for the publication of the great generalizations of van't Hoff and Arrhenius, may justly be regarded as dates of outstanding importance in the history of analytical chemistry. To deal with this aspect of the subject at any length before an audience of chemists is quite unnecessary. That the theory of electrolytic dissociation has not met with universal acceptance is of little importance from this point of view, for I believe that even those chemists who regard it with the greatest disfavor would be inclined to admit that no other theory is able to explain so much or is capable of welding the whole chaotic mass of analytical phenomena into such a coherent and harmonious whole.

The manner in which it has contributed to the build-

ing of a serviceable, if not complete, theory of indicators, and its helpfulness in explaining the phenomena of electrolysis, hydrolytic dissociation, and mass action, are too well known to need more than a passing reference.

As a further instance of the fruitfulness of this concept and of its value to analytical chemistry I may mention the application of the conductivity method to the determination of the point of neutrality of liquids. This method, first suggested by Küster and Grütters in 1903, has since received a considerable amount of attention at the hands of a great many workers, and the numerous contributions to the subject by Sørensen, Michaelis and others represent a storehouse of very valuable information in connection with the applicability of certain indicators to special purposes, the preparation of solutions of standard reaction, and the electrometric measurement of hydrogen-ion concentration. This work, which is undoubtedly capable of further development, has already proved of very great value in the investigation of certain bio-chemical problems, and will, no doubt, find extended application in the wider field of technical analysis.

In further exemplification of the close and fruitful connection between physical chemistry and analytical chemistry, I may just refer to the vast amount of work which has been done during comparatively recent years in connection with the colloidal state of matter and in the study of catalytic phenomena.

As showing, moreover, how some of the more recalcitrant physical properties of matter may prove to be of practical importance to the analyst, I may perhaps be permitted to refer to the papers which I have published alone or in collaboration with H. D. Law on the reducing action of hydrogen in its relation to analytical processes. In those papers it has been shown that much depends on the nature of the metallic surfaces from which the hydrogen is evolved. Thus, certain specimens of zinc which, owing to the presence of small quantities of impurities, are useless for the purpose of detecting and estimating minute traces of arsenic by the modified Marsh-Berzelius method, can usually be made suitable by coating the zinc with pure cadmium, thus producing a surface from which the hydrogen is evolved in a state of higher chemical activity.

In the same way, when an electrolytic method of estimating traces of arsenic is employed, much greater sensitiveness is obtained by using a lead or a cadmium rather than a platinum cathode. It is, of course, tolerably certain that the reducing efficiency of hydrogen, whether obtained by the interaction of metal and acid or by an electrolytic process, is dependent upon a number of factors, partly chemical and partly physical, and that the reactions are, in point of fact, very complex. There can, however, be very little doubt that among these factors the question of "potential" or "overvoltage" plays a prominent and important part.

The effect of employing cathodes of different metals in the reduction of arsenious oxide is shown by the following results:—

	Arsenious oxide added.	Arsenious oxide found.	Arsenious oxide left in flask.
Cathode.			
Lead	10	10	—
Cadmium	10	10	—
Tin	10	10	—
Copper	100	10	90
Silver	50	10	40
Nickel	40	20	20
Platinum (black) ..	1000	0	1000
Iron	50	5	45

From this it will be seen that even the overvoltage of metals—a subject which at first sight might appear to be mainly of academic interest—has, in fact, a very direct and important bearing on some of the every day operations of the analytical laboratory.

Time forbids that I should deal at any greater length with this side of the intimate relationship existing between these two branches of our science, and I will now refer briefly to the service rendered by physical chemistry in the direction of increasing the analyst's equipment and of multiplying his means of attack.

* A Lecture delivered before the Chemical Society, and reported in the *Chemical News*.

To the balance, the microscope, and the spectro-scope there have been added from time to time a number of other physical instruments, some of which have revolutionized many of the older branches of analytical chemistry and have even been the means of giving birth to new ones. Whilst in its cruder forms the polariscope goes back to the beginning of the last century, or even beyond, the modern polarimeter is of comparatively recent birth, and since the introduction of the Jellet instrument about 1890, the labors of physicists and opticians have been almost continuously devoted to the perfecting of this highly important analytical appliance. Without it, carbohydrate analysis would to-day have been in a very different position, and many of the problems which confront the analyst in connection with the sugar, starch, confectionery, essential oil, and brewing industries would have been impossible of solution. In addition to these main applications of the polarimeter, there are many others of less importance, and new ones without doubt remain to be discovered.

Next perhaps in importance comes the refractometer, an instrument which finds wide and ever-increasing application in the analytical laboratory. What the polarimeter is to carbohydrate analysis the refractometer is to the analysis of fats and oils, and its assistance has been successfully invoked in the examination of brewing materials, milk serum, sugars, methyl and ethyl alcohols, glycerol and many other natural and artificial products.

The calorimeter in all its forms and with all its modern refinements, as well as the various mercurial, resistance and thermo-electric heat-measuring instruments, represent another section of what, for want of a better term, may be called analytical procedure, for the development of which the chemist is chiefly indebted to the physicist.

In addition to these physical instruments of almost every day use, passing reference may be made to modern spectrographic apparatus, appliances for the determination of electrical conductivity, instruments for the measurement of color and of turbidity, and, lastly—and of most recent introductions—apparatus suitable for making estimations of radioactivity.

I think I have said enough to show the general nature of the relationship existing between physical and analytical chemistry, and to indicate one of the main lines along which the latter branch of our science has advanced during comparatively recent years. Such indeed is the intimacy of the connection that, as new discoveries are made by physical chemists, they will almost inevitably be utilized in the consolidation or extension of that great field of analytical chemistry in which so many of us are proud to labor.

I will now turn for a brief space to another side of my subject. If organic chemistry by its rapid growth, vast importance, and all-compelling interest was responsible for the temporary neglect of analytical chemistry at one stage of its history, it has since made ample amends by furnishing the analytical armory with a number of very important weapons. If it has presented to the analyst innumerable problems of the highest importance, it has also supplied in many cases the means for their solution. To speak more plainly, it has been found during recent years that many of the more or less complex products of the organic laboratory are, in fact, very valuable analytical reagents, and that by their use old problems may often be better solved and new ones successfully attacked.

One of the earliest of these was phenylhydrazine, by the discovery of which in 1878 E. Fischer placed in the hands of chemists a reagent which is now almost as necessary in the analytical as in the purely organic laboratory. In qualitative analysis, it is only necessary to refer to the application of the osazone reaction to the identification of the various sugars, a problem the difficulty of which is only equalled by its importance, whilst in quantitative analysis it has a large sphere of usefulness in the estimation of aldehydes and in the quantitative examination of compounds containing the carbonyl, nitroso- and nitro-groups. In addition to phenylhydrazine itself, considerable use has been found for some of its substituted derivatives, such as *s*-phenylmethylhydrazine, *s*-diphenylhydrazine, and the *p*-bromo- and *p*-nitro-compounds. In this connection, reference may also be made to *p*-naphthylhydrazine, a substance which Ekenstein and Lobry de Bruyn have shown to be of great service in the recognition and separation of certain carbohydrates and for the estimation of vanillin, and to semicarbazide, a substance which has proved so useful in the isolation and identification of the aldehydic and ketonic constituents of many essential oils.

As further examples of organic compounds which have been successfully applied to the identification and estimation of organic substances of technical importance, mention may be made of phloroglucinol, digitonin, picric acid and picrolonic acid. The estimation of pentoses and pentosans in certain foodstuffs and in many agricultural products is often a matter of importance, and, as is well known, the method almost invariably adopted consists in distilling the substance under investigation with hydrochloric acid and estimating the furfural in the distillate. For this purpose, phloroglucinol, which forms with furfural a sparingly soluble compound—the so-called phloroglucide—is often made use of. In the same way, methyl-pentoses and methyl-pentosans can be estimated as the corresponding phloroglucinol compound. Further than this, the difference in the solubility in alcohol of the two phloroglucides affords a means for the approximate separation of the pentoses (for example, arabinose and xylose) and the methylpentoses (for example, rhamnose and fucose).

In 1910 Widaus made the discovery that one molecule of cholesterol is capable of uniting with one molecule of digitonin to form a compound of high molecular weight ($C_{57}H_{104}O_{22}$) which is very insoluble, and can consequently be conveniently employed for the estimation of the former substance—a matter of considerable importance to physiological and occasionally to technical chemists. Since digitonin also forms a similarly insoluble compound with phytosterol, it has been employed for the purpose of obtaining either or both of these alcohols in a pure condition prior to converting them into their acetates, as in the ordinary Bömer test. In this way, the detection of vegetable oils of animal origin, or vice versa, is much facilitated.

The extensive use made of picric acid for the identification, and occasionally for the estimation, of alkaloids and other bases is too well known to need more than a passing reference, and more recently picrolonic acid (dinitrophenylmethylpyrazolone) has been employed for the same purpose. The picrolonates are in some cases less readily soluble than the corresponding picrates, crystallize well, and are often very characteristic. The importance of adding to our means of identifying such substances as arginine, histidine, lysine, guanidine and other physiologically important bases will be obvious to all who have followed the developments of modern biochemistry.

It will be seen that the instances I have given above are all cases in which one organic compound has been made use of for the identification or estimation of another. I will now refer to a more interesting and, in a sense, more significant application of certain organic compounds, namely, to the detection and estimation of what may be conveniently described as the simpler inorganic acids and bases.

One of the earliest of these is the *m*-phenylenediamine test for nitrous acid, for which we are indebted to Peter Griess. Already in 1870 Griess had recommended the use of one of the diaminobenzoic acids for the detection of nitrous acid, and in 1878 he proposed the use of the above reagent as being much more sensitive, and the method was worked out on the quantitative side about the same time by Preusse and Tie-mann. In the following year Griess published a further paper, in which he recommended for the same purpose the use of a mixture of sulphanic acid and α -naphthylamine—a method which is occasionally ascribed to Ilosvay, who merely recommended the substitution of acetic acid for a mineral acid as the acidifying medium.

Another well-known colorimetric method for the detection and estimation of minute quantities of nitrous and nitric acids is due to Lunge, and involves the employment of diphenylamine. Although, unfortunately, not specific, it has proved of the greatest service in the estimation of minute traces of nitrogen acids in sulphuric acid, milk and other technical products.

A good many other organic compounds, such as phenolsulphonic acid and resorcinol, have been recommended at various times for the detection and estimation of nitrates and nitrites, but it will not be necessary to refer to these in any detail. It will, of course, be readily understood, that the nature of my subject—even if time permitted—renders it unnecessary for me to deal by way of illustration with more than a few of the instances in which organic compounds have been pressed into the service of this branch of general analytical chemistry, and I shall confine my attention to those methods which have been very thoroughly tested and have been elevated to the rank of standard processes.

[TO BE CONTINUED]

Sulfate of Iron and Wood

SOME forty-five years ago, some houses were built in the suburbs of London on clay soil, and the walls were stained with the common sulfate of iron stain and tuck-pointed in black, this making the houses look smart. The gardens were drained at the same time with agricultural pipes, these being covered with shavings to keep out loose earth, and the writer well recollects that the spare stain from the brickwork was thrown on these shavings in one place. Last year a brick workshop was put up in the garden where the stain was poured down, this part being opened up for foundations. The shavings and a lath or two used for stirring the stain were turned up and were nearly as sound as when put in, while the laths were quite sound, those which had not been saturated having become a semi-dry, crumbly mass. It would seem from this, that in many cases where wood is buried, a saturation with sulfate of iron in strong solution would not be a bad experiment to try where clayey soils are concerned, although, of course, one result cannot be taken as a precedent.—*The Practical Engineer*.

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